Chapter 4: Flood, Earthquake and Sea-Level Rise Risk Management

1 Overview and Key Findings

The present-day Delta is defined geographically and hydraulically by levees, creating a landscape that differs from that of the historic, natural Delta. In place since the early 20th century, the current-day levee system provides flood control, channels water for urban and agricultural uses, and creates an environment unique in California. It is the overall policy of the State to “protect, maintain, and, where possible, enhance and restore the overall quality of the Delta environment, including, but not limited to, agriculture, wildlife habitat, and recreational activities.”[17] It is also the policy of the State to “improve flood protection by structural and nonstructural means to ensure an increased level of public health and safety.”[18] Taken together, these two policies necessarily mean that the State is committed to maintaining and enhancing the Delta levees in more or less their present configuration.

For the purposes of this study, an up-to-date map of Delta levees was created. This map serves as the basis for an updated tabulation of levee lengths, which shows that in the Legal Delta, there are just under 1,000 miles of levees, of which 380 miles are project levees constructed by the U.S. Army Corps of Engineers (USACE), and an additional 63 miles are urban non-project levees, as defined by recent State legislation. Subtracting from the total the urban levees and levees in the north and south Delta that are primarily flood-control levees leaves around 650 miles of core levees, which protect lands below sea level in the Primary Zone of the Delta. Of these core levees, 193 miles are project levees that are primarily located along the Sacramento River. The remaining approximately 460 miles of core levees need to be maintained and enhanced by the State and the local reclamation districts.

Of this 460 miles of levees, only about 50 miles clearly fall below FEMA’s Hazard Mitigation Plan (HMP) “standard” and 100 miles or more are already at or about the Corps of Engineers Delta-specific PL 84-99 standard. It has been the goal of the State and federal governments, working through the Department of Water Resources (DWR), the U.S. Army Corps of Engineers (USACE), and the local reclamation districts, to meet the PL 84-99 standard since 1982 when DWR and USACE produced a joint report on the Delta levees which recommended the basis for this standard. Funds currently in the pipeline should bring the Delta levees close to achieving this goal, and when these funds have been expended, more than $698 million will have been invested in improvements to the Delta levees since 1973. These improvements have created significantly improved Delta levees through modern engineering and construction, making obsolete the historic data that is still sometimes used for planning or predicting rates of levee failure.

Three approaches can help all jurisdictions and planners further reduce the risks resulting from the failure of the Delta levees. These approaches are: (1) build even more robust levees, (2) improve both regular maintenance and monitoring and flood-fighting and emergency response following earthquakes, and (3) improve preparedness for dealing with failures after they occur. With regard to the first approach, the big question with respect to the core Delta levees is not whether they should be improved to the Delta-specific PL 84-99 standard—that is already happening—but whether, in order to comply with the policies of the State quoted above, they should be improved to a higher standard in order to address hazards posed by not only floods, but also earthquakes and sea-level rise. These improvements would also allow for planting

[17] Delta Reform Act, 2009, W.C. 29702 (b)
[18] W.C. 29702 (d)

vegetation on the water side of the levees—an essential component Delta ecosystem repair. These further-improved levees would have wider crowns to provide for two-way traffic and could easily be further widened at selected locations to allow the construction of new tourist and recreational facilities out of the statutory floodplain. Improvement of core levees to this higher standard would likely cost in the order of $1–2 billion. Three broad sources of funding are identified for these improvements in Section 5 of this chapter.

2 Background

The history of the Delta levees is relatively well-known (Thompson, 1957[19]; Mount and Twiss, 2005[20]; DRMS, 2009[21]; Delta Stewardship Council Flood Risk White Paper, 2010[22]; Zuckerman, 2011[23]) and is not repeated in its entirety here. Some of the levees in the Delta are flood-control project levees, built by the federal government and turned over to the State for maintenance, but most of the Delta levees were built and are maintained by local reclamation districts. The State has also passed responsibility for maintenance of most of the flood-control project levees to the local reclamation districts. A good summary of the history and current status of the Delta levees is also provided in a technical memorandum prepared for the Department of Water Resources (DWR) by outside consultants,[24] and referenced subsequently as the DWR Technical Memorandum. This document was only released for public review on July 15, 2011. Both the technical memorandum and the related "Framework for Department of Water Resources Investments in Delta Integrated Flood Management"[25] are in draft form, have only just been released for public review and comment, and are subject to change, but the basic findings of the technical memorandum are unlikely to change and several of its findings are mentioned herein.

All the Delta levees that are currently being maintained are shown in Figure 8 and are listed in Table 1. For comparison, a reconstruction of the historic Delta based on Atwater (1982)[26] is shown in Figure 9. Figure 9 shows that the historic Delta contained no large expanses of open water, but instead was comprised of a dendritic system of channels and sloughs that traversed generally marshy terrain. Natural levees, created along the edges of major waterways, were overtopped only in high water events and supported riparian and even upland vegetation. When the modern Delta was created by diking and dredging in the late 19th century and very early 20th centuries, some of the man-made levees were constructed over the natural levees, but many were not. Those waterways that were created by dredging do not have bordering levees that were founded on natural levees. In many other cases the modern levees were not sited directly over the natural levees. Sketches developed by KSN Inc. illustrating the history of development of both the dredger cuts and other modern levees are shown as Figures 10 and 11

[19] Thompson, J. (1957), Settlement Geography of the Sacramento–San Joaquin Delta, California, dissertation, Stanford University.
[20] Mount, J.F. and R. Twiss (2005), Subsidence, sea level rise, seismicity in the Sacramento–San Joaquin Delta, San Francisco Estuary and Watershed Science, v. 3, article 5, 2005.
[21] California Department of Water Resources (2009), Delta Risk Management Strategy Final Phase 1 Report, http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/phase1_information.cfm.
[22] Delta Stewardship Council (2010), Flood Risk White Paper, http://deltacouncil.ca.gov/delta-plan.
[23] Zuckerman, T. (2011), Comments on the Third Staff Draft of the Delta Plan, Delta Stewardship Council, http://deltacouncil.ca.gov/public-comments/read/195.
[24] California Department of Water Resources (2011), Staff DRAFT, "Background / Reference Memoranda, Delta Region Integrated Flood Management Key Considerations and Statewide Implications", July 15, 2011.
[25] California Department of Water Resources (2011), DRAFT V3 DHF and SMB, "A Framework for Department of Water Resources Investments in Delta Integrated Flood Management," February 14, 2011.
[26] Atwater, B. (1982), Geologic Maps of the Sacramento–San Joaquin Delta, California, USGS Miscellaneous Field Studies Map MF-1401.

Figure 8 Delta Levees

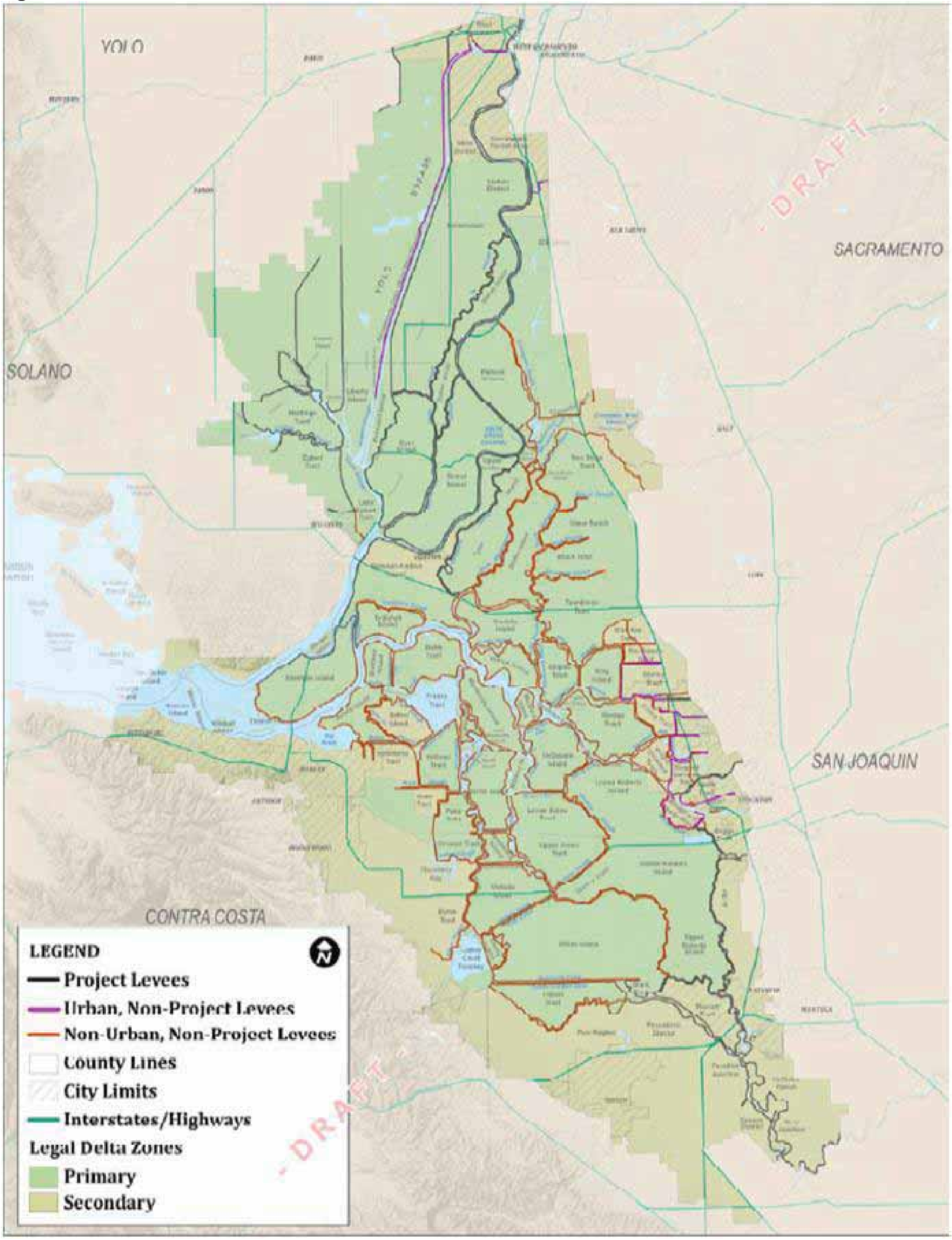


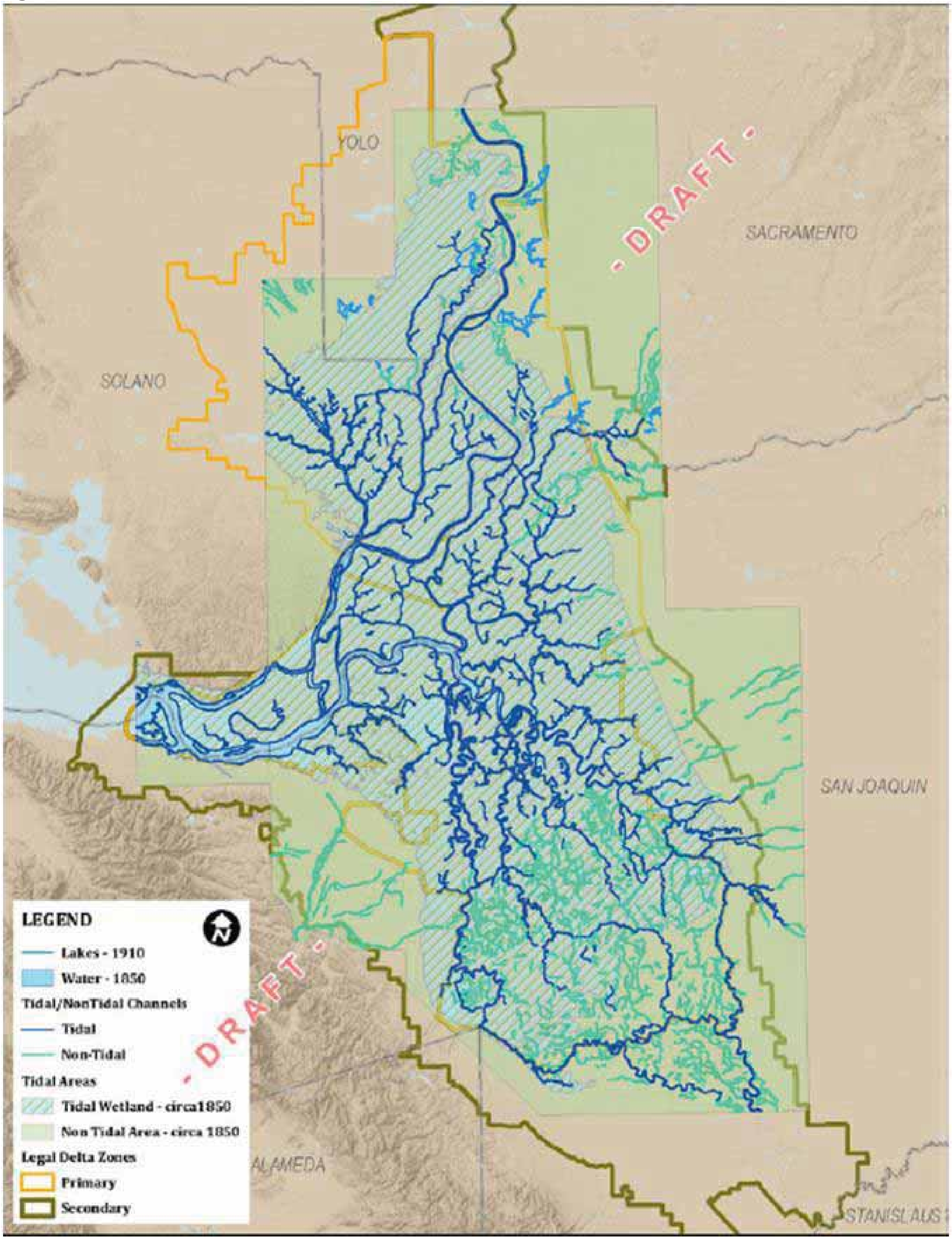
Table 1 Delta Levees (Part 1 of 2)

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(I)
List	District	Reclamation	Miles of Levee				
Number	Number	District	Project	Urban NP	NP-NU	Total	Core
1	556	Andrus Island	11.2	0.0	0.0	11.2	Yes
2	2126	Atlas Tract	0.0	2.3	0	2.3	No
3	2028	Bacon Island	0.0	0.0	14.3	14.3	Yes
4		Bear Creek	3.3	0.0	0.0	3.3	No
5		Bethel Island	0.0	0.0	11.5	11.5	Yes
6	2042	Bishop Tract	0.0	6.5	1.6	8.1	No
7	404	Boggs Tract	4.0	0.6	0.6	5.2	No
8	756	Bouldin Island	0.0	0.0	18.0	18.0	Yes
9	2033	Brack Tract	0.0	0.0	10.0	10.0	Yes
10	2059	Bradford Island	0.0	0.0	7.4	7.4	Yes
11	317/407	Brannan-Andrus	17.5	0.0	10.1	27.6	Yes
12	800	Byron Tract	0.0	0.0	9.5	9.5	No
13	2098	Cache Haas	10.9	0.0	0.0	10.9	No
14	2086	Canal Ranch	0.0	0.0	7.5	7.5	Yes
15	2117	Coney Island	0.0	0.0	5.5	5.5	Yes
16	2111	Dead Horse Is.	0.0	0.0	2.6	2.6	Yes
17	2137	Dutch Slough	0.0	0.0	4.1	4.1	No
19	536	Egbert Tract	10.6	0.0	1.8	12.4	No
20	813	Ehrheart	1.8	0.0	3	4.8	No
21	2029	Empire Tract	0.0	0.0	10.5	10.5	Yes
22	773	Fabian Tract	0.0	0.0	18.8	18.8	Yes
23	2113	Fay Island	0.0	0.0	1.6	1.6	Yes
24	1002	Glanville Tract	0.0	0.0	7.1	7.1	No
25	765	Glide	1.7	0.0	0.0	1.7	No
26	3	Grand Island	28.7	0.0	0.0	28.7	Yes
27	2060	Hastings Tract	15.6	0.0	0.0	15.6	No
28	999	Holland Land	32.2	0.0	0	32.2	Yes
29	2025	Holland Tract	0.0	0.0	11.0	11.0	Yes
30	799	Hotchkiss Tract	0.0	0.0	6.7	6.7	No
31	830	Jersey Island	0.0	0.0	15.5	15.5	Yes
32	2038/2039	Jones Tract	0.0	0.0	18.4	18.4	Yes
33	2085	Kasson	6.3	0.0	0.0	6.3	No
34	2044	King Island	0.0	0.0	9.1	9.1	Yes
35	369	Libby McNeil	1.0	0.0	2.8	3.8	Yes
36	1608	Lincoln Village	0.0	3.3	0.6	3.9	No
37	307	Lisbon	6.6	0.0	0.0	6.6	No
38		Maint Area 9	12.6	1.5	0.0	14.1	No
39	2027	Mandeville Island	0.0	0.0	14.3	14.3	Yes
40	2030	McDonald Island	0.0	0.0	13.7	13.7	Yes
41	2075	McMullin	7.4	0.0	0.0	7.4	No
42	2041	Medford Island	0.0	0.0	5.9	5.9	Yes
43	150	Merritt Island	17.7	0.0	0.0	17.7	Yes
44	2107	Mossdale 2	4.3	0.0	0.0	4.3	No
45	17	Mossdale Tract	15.8	0.0	0.0	15.8	No
46	1007	Naglee Burke Tract	0.0	0.0	7.6	7.6	No
47	348	New Hope Tract	0.0	0.0	15.1	15.1	Yes
48	2064	Orwood-Palm Tract	0.0	0.0	14.4	14.4	Yes

Table 2 Delta Levees (Part 2 of 2)

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(I)
List	District	Reclamation	Miles of Levee				
Number	Number	District	Project	Urban NP	NP-NU	Total	Core
49	2095	Paradise	4.9	0.0	0.0	4.9	No
51	2058	Pesadero Tract	6.6	0.0	0	6.6	No
52	2104	Peters	6.8	0.0	0.0	6.8	No
53	551	Pierson District	6.8	0.0	7.3	14.1	Yes
54	2090	Quimby Island	0.0	0.0	7.0	7.0	Yes
55	755	Randall	1.8	0.0	0.0	1.8	No
56	744	Rec District	3.9	0.0	0.0	3.9	No
57	673	Rec District	0.2	0.0	0.0	0.2	No
58	2037	Rindge Tract	0.0	0.0	15.8	15.8	Yes
59	2114	Rio Blanco Tract	0.0	1.8	4.1	5.9	No
60	2064	River Junction	9.7	0.0	0.0	9.7	No
61	524/544/	Roberts Island	16.4	0.0	34.1	50.5	Yes
62		Rough/Ready Island	0.0	5.5	0.0	5.5	No
63	501	Ryer Island	20.2	0.0	0.0	20.2	Yes
64	2074	Sargent Barnhart	2.1	2.9	2.5	7.5	No
65	341	Sherman Island	9.6	0.0	9.9	19.5	Yes
66	2115	Shima Tract	0.0	7.0	7.3	14.3	No
67		Shin Kee Tract	0.0	0.0	3.1	3.1	No
68	1614	Smith Tract	5.9	3.3	1.0	10.2	No
69	2089	Stark	2.8	0.0	0.8	3.6	Yes
70	38	Staten Island	0.0	0.0	25.4	25.4	Yes
71	2062	Stewart Tract	12.2	0.0	0.0	12.2	No
72	349	Sutter Island	12.4	0.0	0.0	12.4	Yes
73	548	Terminous Tract	0.0	0.0	20.0	20.0	Yes
74	1601	Twitchell Island	2.5	0.0	9.3	11.8	Yes
75	563	Tyler Island	12.1	0.0	10.3	22.4	Yes
76	1	Union Island	1.1	0.0	28.8	29.9	Yes
77	2065	Veale Tract	0.0	0.0	5.0	5	No
78	2023	Venice Island	0.0	0.0	12.4	12.4	Yes
79	2040	Victoria Island	0.0	0.0	15.1	15.1	Yes
80	554	Walnut Grove East	0.9	0.0	2.5	3.4	Yes
81	2094	Walthall	3.2	0.0	0.0	3.2	No
82	2026	Webb Tract	0.0	0.0	12.9	12.9	Yes
83	828	Weber	0.0	1.7	0.6	2.3	No
84	900	West Sacramento	15.0	26.6	1.6	43.2	No
85	2096	Wetherbee	0.2	0.0	0.0	0.2	No
86	2072	Woodward Island	0.0	0.0	8.9	8.9	Yes
87	2119	Wright-Elmwood Tract	0.0	0.0	7.1	7.1	No
88	2068	Yolano	8.8	0.0	0.0	8.8	No
89		Yolo Bypass Unit 4	4.2	0.0	0.0	4.2	No
	Core Total		193.1	0.0	458.5	651.6	
	Grand Total		379.5	63.0	533.4	975.9	

Figure 9 The Historic Delta



It is well known that many of the Delta islands have subsided since they were first diked so that most of the land surfaces within these islands are now below sea level. However, the rates of subsidence have decreased markedly in recent years. That issue is discussed in more detail in Appendix D. Reasonably current land surface elevations interpreted from DWR's 2007 LiDAR surveys are shown in Figure 12.[27] The mostly deeply subsided land is about 30 feet below sea

[27] Based on DRMS GIS data set developed by URS Corporation and provided by DWR.

level, but only a fraction of the Legal Delta is more than 15 feet below sea level, as shown by the dark blue coloring in Figure 12. The subsidence has been restricted to the areas of the western and central Delta that are underlain by peat, and there are extensive areas to the north and the south within the Legal Delta that have not been affected by subsidence.

Figure 10 Construction of Delta Levees

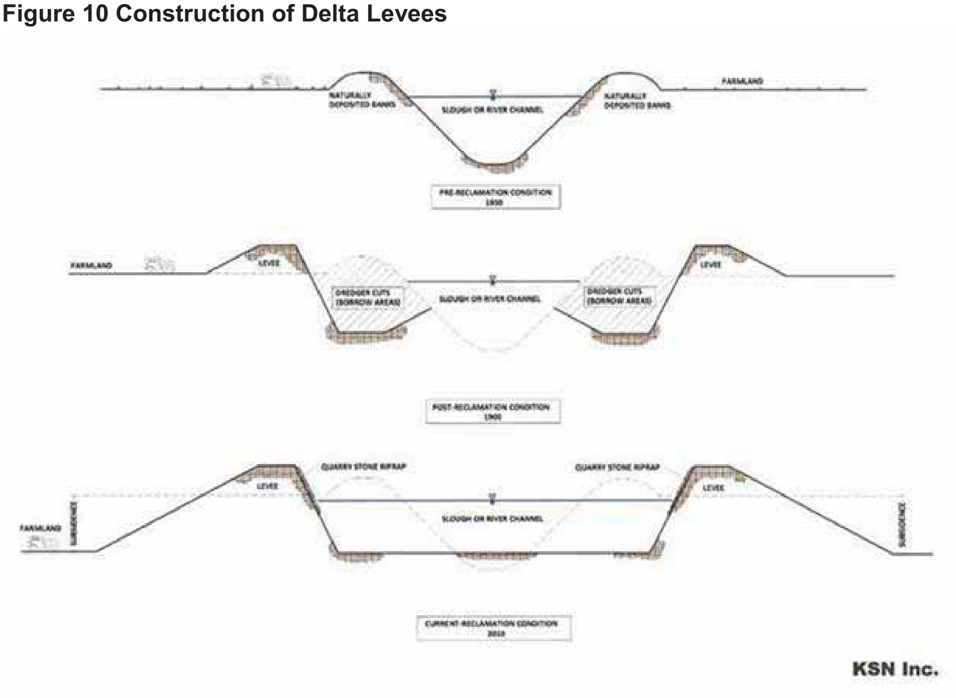


Figure 11 Construction of Dredger Cuts

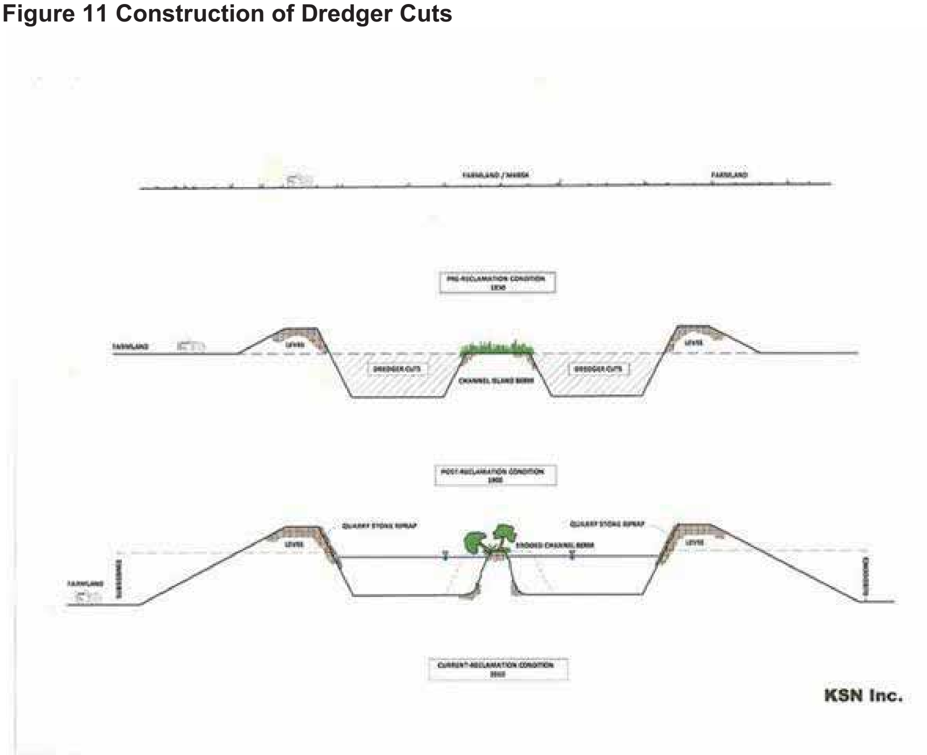
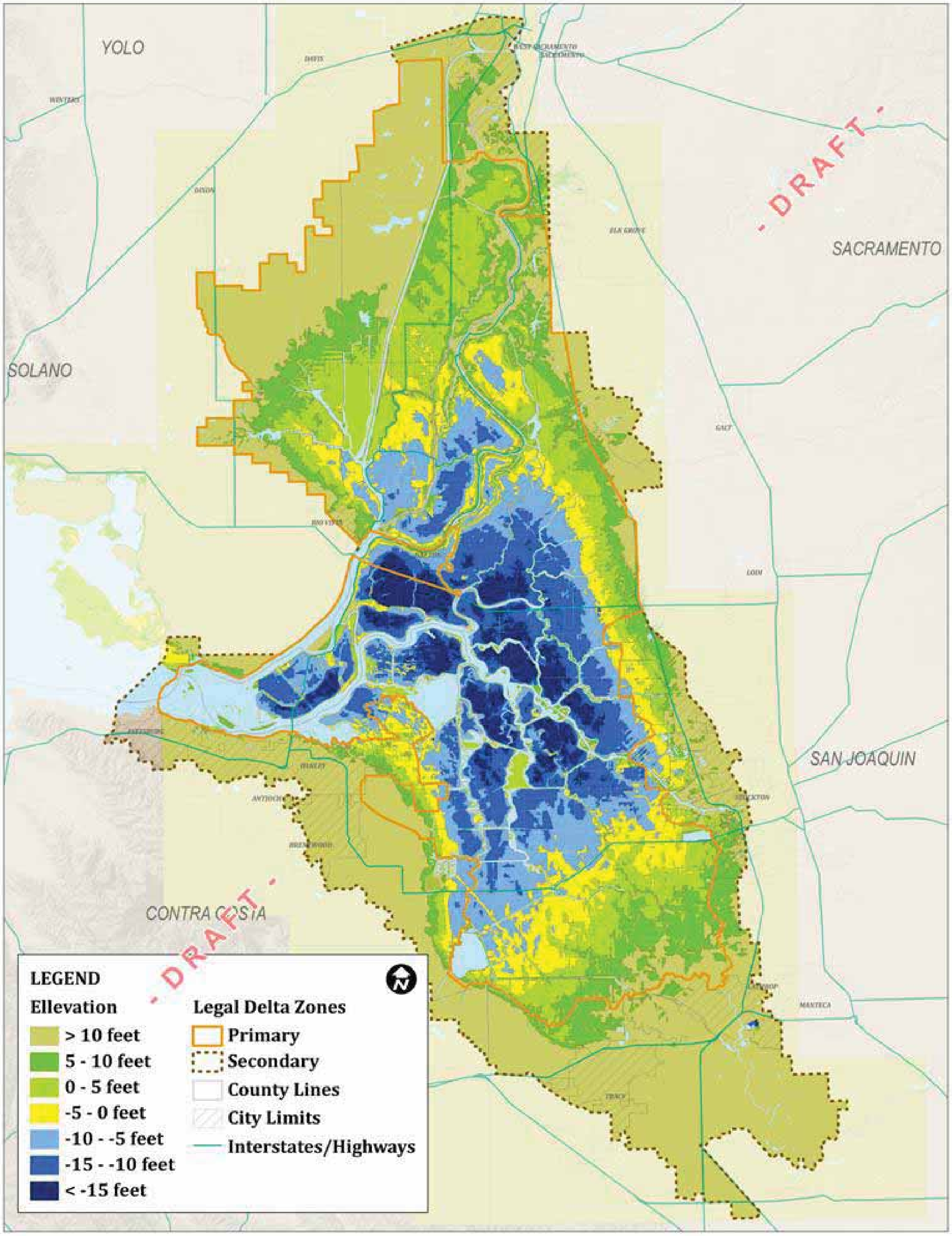


Figure 12 Current Elevations of Delta Land Surface



There is a popular impression that there are 1,100 miles of Delta levees all in poor condition. This has led to concern that there is a high probability of widespread failures in the event of flooding, earthquakes, or sea-level rise. While most Delta levees need further improvement, many miles of the Delta levees are actually in quite good condition. Even without survey measurements, touring the Delta by boat during a high-water event reveals that while the condition of the levees is variable, most levees appear to have adequate freeboard. Selected photographs taken during a period of relatively high water in March 2011 are shown in Appendix B. Casual inspection is inadequate to ensure that these levees are, and will remain, in good condition, but there are existing programs to maintain and improve the levees, and these programs can be further strengthened.

Only the levees within the Legal Delta that are currently being maintained and are candidates for further improvement are shown in Figure 8. Levees such as those around Liberty Island and Prospect Island, which lie within the Yolo Bypass, and the levees around the McCormack–Williamson Tract, which have always been height limited and are slated for removal, are not shown. With the removal of levees that are not being maintained and dry-land levees, the total length of the Delta levees is just under 1,000 miles. The division of these levees into project, non-project urban, and other non-project levees and their significance is explained in the following sections. But, as noted in the DWR Technical Memorandum: "The Delta's system of levees … and interconnected channels operate as a single, multi-function, flood management system. The failure of one levee can increase the risk of other levee failures, increasing the need for levee maintenance on adjoining islands in an effort to prevent additional levee failures. In addition, the large benefits to regions outside the Delta make it difficult to consider one island or tract separately from all others."

The remainder of this chapter is divided into three sections. The next section categorizes the different types of Delta levees, sums up the number of miles of levee in each category, and makes a qualitative assessment of their present condition. The following section addresses the three broad options that are available to reduce the risk of damage resulting from levee breaches, where risk is loosely defined as the product of the probability of a failure and the consequences of that failure. An economic analysis of these alternatives might lead to optimizing the appropriate investments, but that beyond the scope of the present study. The final section addresses in more detail the costs of pursuing the first option, which is to further improve the levees so that they are more resistant to earthquake loadings, can more easily be raised as necessary to accommodate possible sea-level rise, and have a broader cross-section, which would allow planting of native vegetation on the water side.

3 Status of Delta Levees

3.1 Categories of Levees

3.1.1 Project Levees

Project levees were constructed by the U.S. Army Corps of Engineers (USACE) as part of federal-state flood-control projects and were turned over to the State for operations and maintenance. The State has in turn generally passed on the responsibility for routine maintenance to local reclamation districts, although the Paterno Decision[28] confirmed the State's continued basic liability with respect to these levees. The State Plan of Flood Control Descriptive Document, dated November 2010, delineates project levees and provides the names of the local maintenance agencies. Project levees within the Delta are identified in Figure

[28] *Paterno v. State of California* (2003) 113 Cal.App.4th 998.

8. These levees were built to standards that generally exceed the PL 84-99 criteria described below.

3.1.2 Urban Levees

SB 5,[29] enacted in 2007, calls for a minimum of 200-year flood protection for urban and urbanizing areas in the Sacramento–San Joaquin Valley. SB 5 also limits the conditions for further development if this level of flood protection has not been achieved, conditions have not been imposed on the development to provide this level of flood protection, or adequate progress towards achieving this level of protection cannot be shown. DWR is developing criteria for these urban levees that will generally be more stringent than the current criteria for project levees. These criteria are discussed below.

Recognizing the need for higher levels of flood protection, the major urban areas in the Sacramento–San Joaquin Valley have each formed a Joint Powers Authority (JPA) to implement levee improvements, in part using funds from the DWR Early Implementation Program. Three of these JPAs overlap the Legal Delta—West Sacramento Area Flood Control Agency (WSAFCA), Sacramento Area Flood Control Agency (SAFCA), and San Joaquin Area Flood Control Agency (SJAFCA).

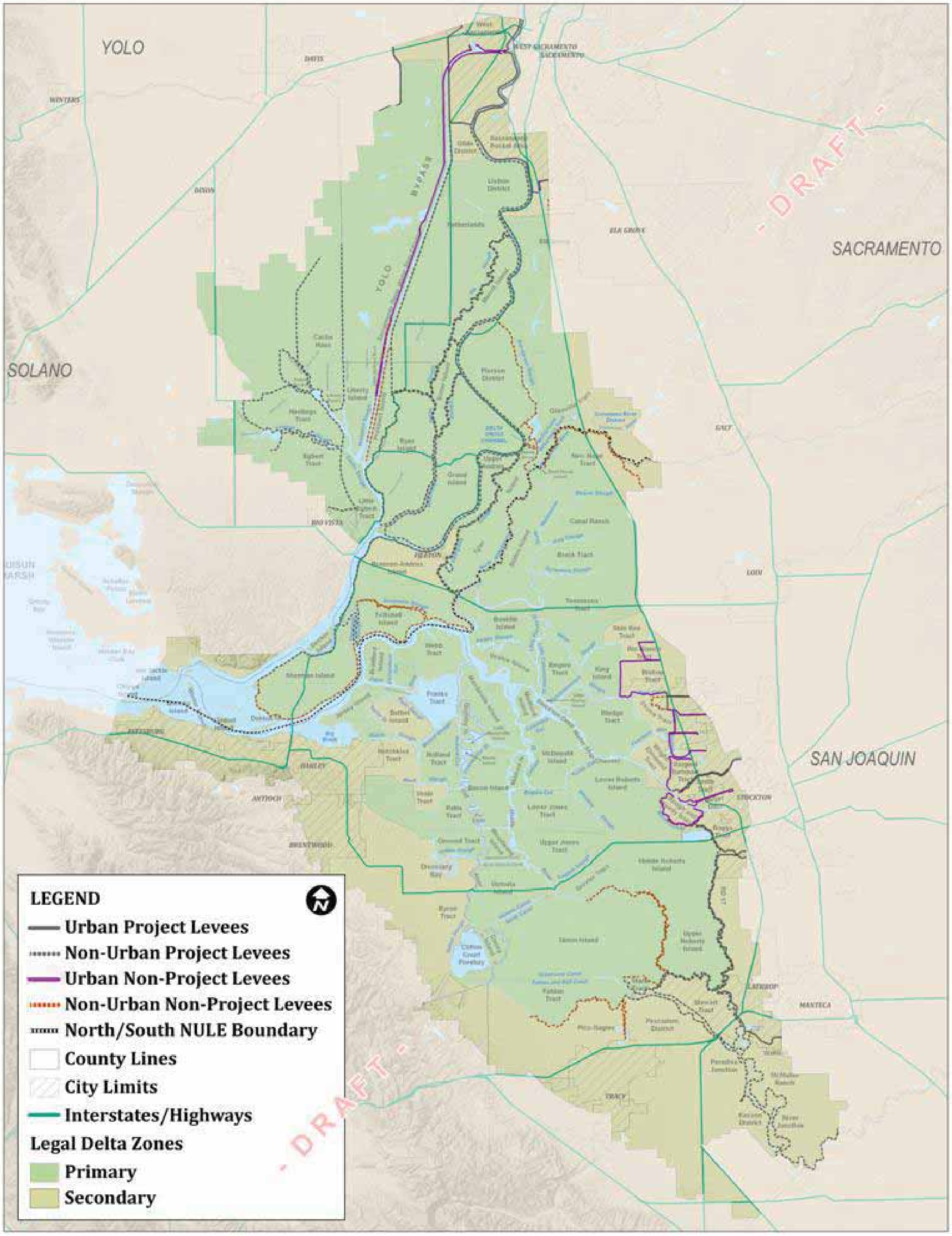
Prompted by the Paterno Decision and SB 5, DWR is undertaking a major investigation of both riverine and Delta levees that is divided into two components, the Urban Levee Evaluations (ULE), and the Non-Urban Levee Evaluations (NULE) (Inamine et al, 2010).[30] These evaluations include detailed site investigations and some analyses and are intended to inform the Central Valley Flood Protection Plan (CVFPP) as to the likely level of effort that will be required for final design and the construction of improvements. Those levees within the legal Delta that are included in ULE and NULE are shown in Figure 13,[31] superimposed on the mapping of project and non-project levees. Some of these DWR-designated urban levees are project levees and some are not. Because there are special requirements for urban levees, as well as special sources of funding for improvements, the non-project urban levees are also identified in Figure 8.

[29] SB 5 (Machado) was the centerpiece of a far-reaching flood control package of legislation. It requires the Department of Water Resources to prepare a Central Valley Flood Protection Plan and allows local jurisdictions to prepare their own plans only if they include specified elements that are consistent with the state plan.

[30] Inamine, M. et al. (2010), California's Levee Evaluation Program, US Society of Dams, 30th Conference, Sacramento, April.

[31] Based on GIS data set provided by DWR and URS Corporation.

Figure 13 Urban and Non-Urban Levee Evaluation Programs



3.1.3 Other Special Levees

While the Delta levees were originally constructed to protect agricultural lands and the small communities that developed primarily along the shipping routes up the Sacramento River, they now are critically important to preserving water quality, to through-Delta conveyance of water, and to the vast array of infrastructure that criss-cross the Delta. The islands that are critical to these functions are discussed and illustrated in Appendix C. It may be seen in Appendix C that few if any islands are not also critical to something else besides agriculture and the Legacy Communities.

3.1.4 Summary

As may be seen in Table 1,[32] a total of just under 1,000 miles of levees are currently being maintained within the Legal Delta. But of these, 443 miles are either project or urban levees. If these levees are subtracted from the total of 976 miles, there are only 553 miles that need to be maintained and perhaps improved by the State and the reclamation districts. The DWR Technical Memorandum makes a distinction between non-project levees that have special status in the California Water Code and are eligible for State assistance and other levees that might be owned by public agencies or private entities that are not eligible for State assistance. The Technical Memorandum indicates that those levees eligible for State assistance are shown on page 38 of the Delta Atlas.[33] The lengths of the non-project levees shown in Figure 8 and listed in Table 1 are generally consistent with those shown on page 38 of the Delta Atlas. The total of 596 miles of non-project levees listed in Table 8 is less than the 732 miles cited in the Technical Memorandum principally because this analysis omits restricted-height levees such as those surrounding the McCormack–Williamson Tract and those in the Yolo Bypass.

If urban areas and levees that are primarily flood-control levees in the north and south Delta are excluded from the total count, there are only about 650 miles of core levees which protect lands below sea level in the Primary Zone. Of these core levees, 193 miles are project levees, primarily located along the Sacramento River. That leaves approximately 460 miles of core levees that need to be maintained and enhanced for the State and the local reclamation districts. Of this sub-set, over 100 miles already exceed the PL 84-99 standard that is discussed below, leaving some 350 miles in need of improvement to the PL 84-99 standard.[34] While the project and urban levees may have issues with encroachment penetrations and vegetation, there are different mechanisms for dealing with these issues; the project and urban levees are fundamentally flood-control levees rather than levees that are key to protecting water quality, the conveyance of water through the Delta, and protecting and enhancing the Delta as a place.

All of the islands shown in Appendix C, which have levees protecting infrastructure or critical facilities of one form or another, are superimposed in Figure 14. The present value or the replacement cost of this infrastructure is not known with any precision, but it is clearly measured in billions of dollars.

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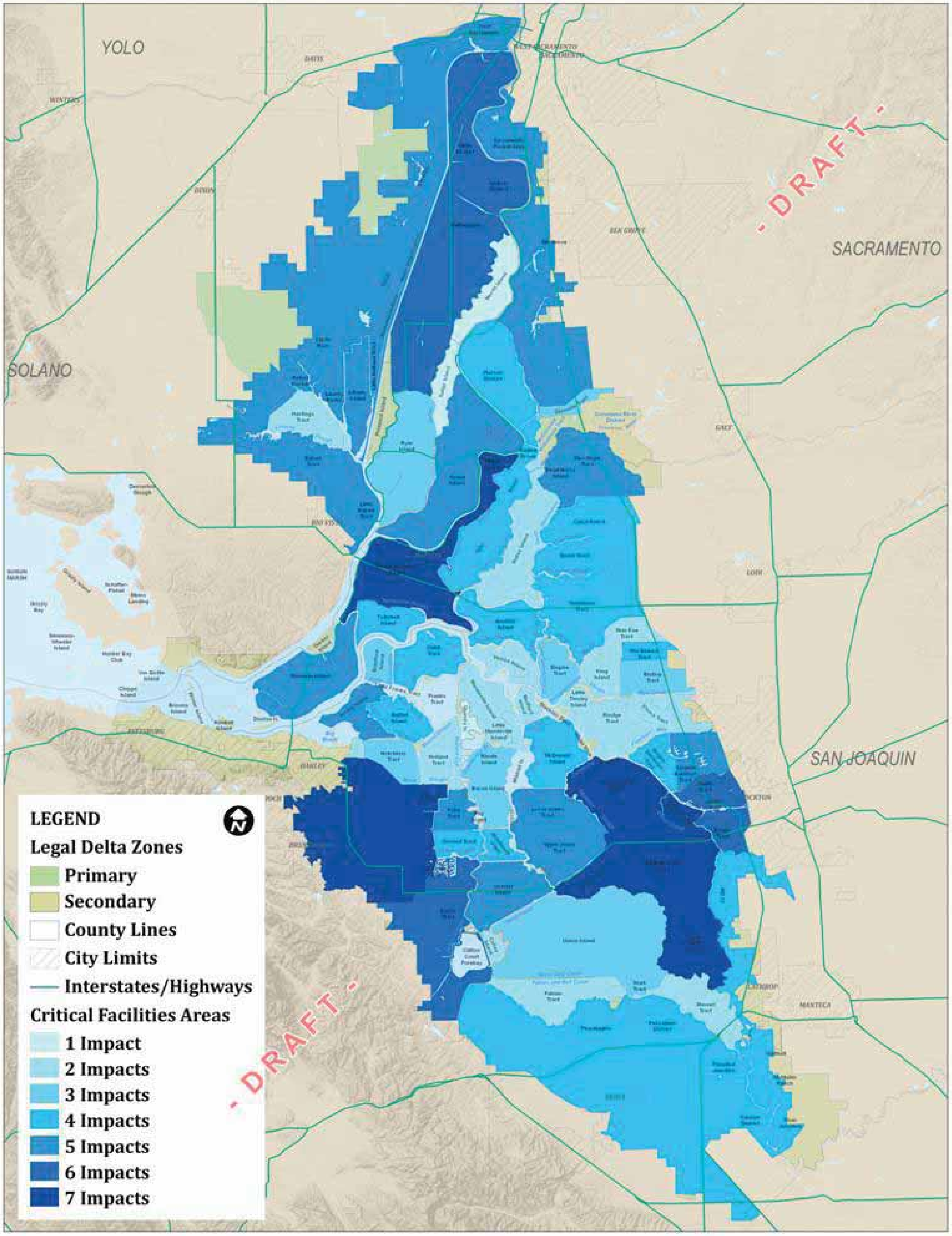
[32] The levee lengths listed in Table 1 have been generated from the GIS data used to develop Figure 1. That GIS data was based on the 2007 DWR LiDAR surveys as interpreted by URS Corporation and provided by DWR. Some, but not all, of the lengths have been cross-checked with ground survey data provided by reclamation district engineers.

[33] http://baydeltaoffice.water.ca.gov/DeltaAtlas/index.cfm

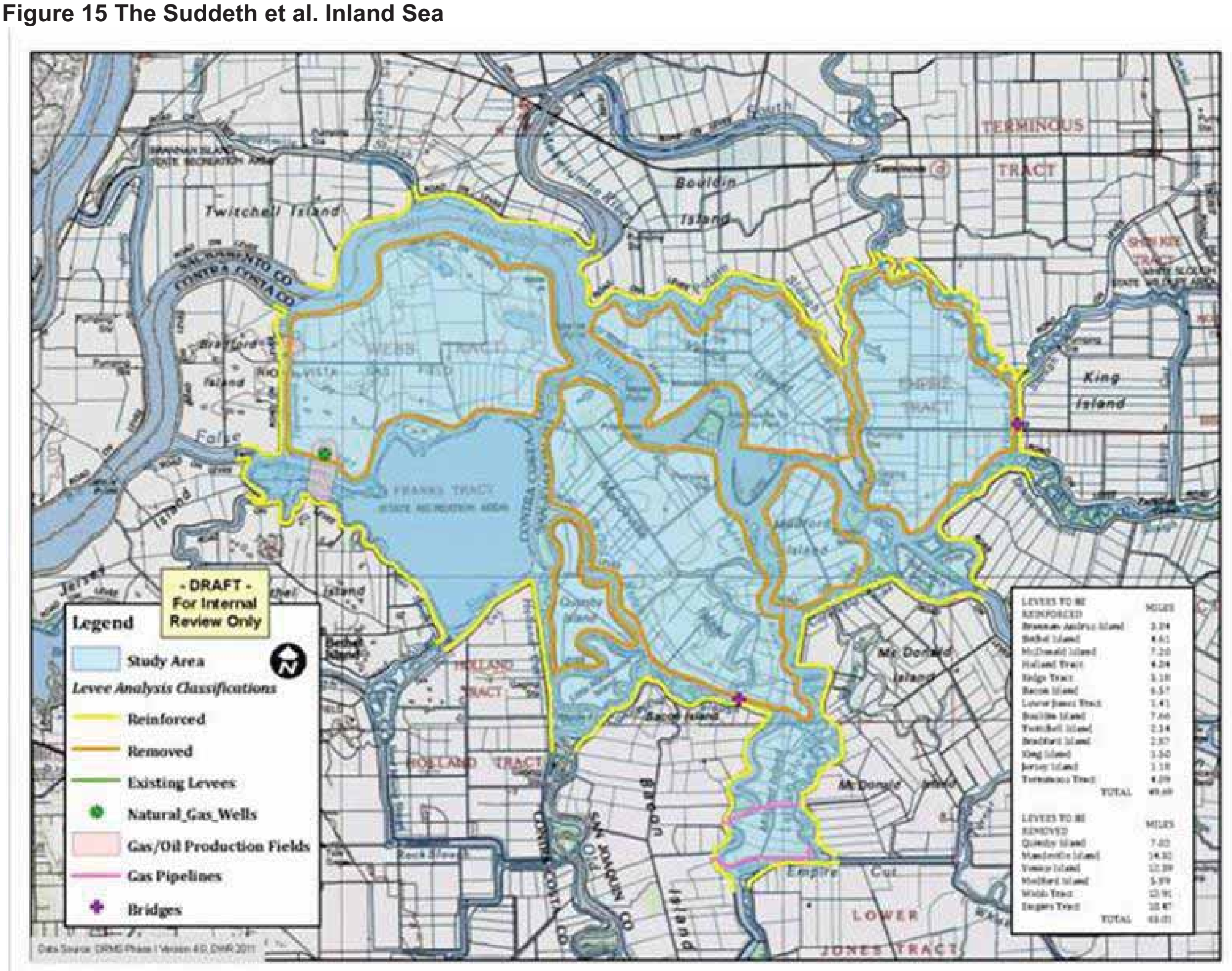
[34] Based on discussions with reclamation district engineers. These estimates will be refined and formalized in the 5-year plans that are now required as a prerequisite for State funding but the preparation of these 5-year plans has been delayed by delays in releasing the funding to develop them.

Figure 14 All Islands Containing Critical Facilities



The principal islands that are relatively free of major infrastructure are Webb, Venice, Empire, Medford, Mandeville, and Quimby, although the City of Stockton is close to completing major water supply facilities on Empire Tract. Suddeth et al. (2010)[35] and Mount (2011) have proposed that consideration be given to converting these islands to open water. The merits and economics of that proposal are discussed further in Chapter 6, but these six islands and the levees that would surround the resulting inland sea are shown in Figure 15. The total length of the levees around the six islands is 63 miles, and the total length of the surrounding levees that would have to be improved to a higher standard to deal with higher wave heights and seepage is approximately 50 miles. If Webb Tract, which is one of the eight western islands called out for their importance to protecting against salinity intrusion, and Empire Tract, which houses the new City of Stockton water intake, were to be omitted from the list, the length of the levees removed would drop to 43 miles. But, the length of levees that would need to be improved would only drop to approximately 45 miles.

Figure 15 The Suddeth et al. Inland Sea



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35 Suddeth. R. (2011), Policy Implications of Permanently Flooded Islands in the Sacramento-San Joaquin Delta, UC Davis Center for Watershed Sciences, http://watershed.ucdavis.edu/pdf/Suddeth_Policy_Implications_of_Flooded_Islands_080110.pdf

3.2 Levee Standards

A detailed discussion of the various standards that might apply to Delta levees was given by Betchart (2008).[36] Betchart's list can be simplified into the five standards listed below. Because the Delta is a unique place with unique soil conditions, some levee standards that are applicable elsewhere are not applicable in the Delta. These unique considerations are discussed in Appendix D.

Hazard Mitigation Plan (HMP)

The Hazard Mitigation Plan (HMP) "standard" is not an engineering standard but is a simple geometric levee description that was devised by FEMA in order to establish minimum requirements for federal disaster relief. It provides for a 16-foot crown width, a 1-foot freeboard above the 100-year water surface elevation, minimum 1.5-to-1 waterside slopes, and minimum 2-to-1 landslides slopes. Most existing Delta levees generally meet this standard, but because Delta levees built of or over peat are subject to on-going settlement, there is continuing argument over how literally this standard should be interpreted. The current regulatory position is stated in a MOU signed in February 2010 between Cal EMA and FEMA, as discussed by Betchart (2011).[37] However, notwithstanding its importance to disaster-relief funding, no engineer familiar with the Delta considers the HMP geometry to be adequate for even basic flood protection, and the reclamation districts are generally working towards full compliance with the higher PL 84-99 standard. While there are some miles of levees that pending further improvement waver around the HMP geometry, there are at present only about 50 miles that fall below HMP,[38] and even those levees fall short only by about a foot of elevation. As noted in the DWR Technical Memorandum, while achieving the HMP geometry is not really a goal from an engineering perspective, consistently meeting it is not only a first step towards the real short-term goal, which is PL 84-99, but is also important from the point of view of the State in maximizing automatic federal assistance following any disaster.

While levee standards are generally thought of in engineering terms and vegetation on levees is discouraged, the treatment of levee vegetation is critical in the Delta (and elsewhere in California) where preservation or restoration of riparian habitat is an important goal. Vegetation management guidelines for local, non-project Delta levees that were adopted in 1994 require that the crown and the landside slope and a ten-foot strip along the landside toe must be cleared of visually obstructive vegetation, although mature trees may be retained. All vegetation except for grasses must be removed from the top five feet of the waterside slope. The guidelines suggest that naturally growing vegetation below the cleared area should be pruned or removed only to the extent necessary to insure levee safety and ease of inspection.

Public Law (PL) 84-99

Among other actions, Public Law 84-99 allows the Corps of Engineers to rehabilitate flood protection systems during a disaster. In order to qualify, the flood system must have already been enrolled into the Corps' Rehabilitation and Inspection Program. In 1987, the Sacramento District of USACE established a Delta-specific standard for levees, based on the Bulletin 192-82 joint DWR-USACE study that is described below. Within the legal Delta this standard plus various maintenance and inspection requirements must be met in order to qualify for rehabilitation under PL 84-99. The Corps was careful to note that "the recommended guidelines

[36] Betchart, W. (2008), Delta Levees – Types, Uses and Policy Options, Prepared for Delta Vision, August.
[37] Betchart, W. (2011), Memo to Delta Levees and Habitat Advisory Committee with attached MOU.
[38] Based on discussions with reclamation district engineers. See previous footnote regarding the development of 5-year plans.

are Delta-Specific and they are not intended to establish design standards for the 537 miles of non-federal levees in the Sacramento–San Joaquin Legal Delta, but to provide uniform procedures to be used by the Corps of Engineers in determining eligibility under PL 84-99, as amended." In the preceding Bulletin 192-82 study it had been stated that "while the Corps' design has accounted for small earthquakes, the lack of actual experience of the impacts of earthquakes on Delta soils leaves some doubt that that some, levees, even after rehabilitation, could withstand an earthquake of Richter magnitude 5 or greater if the epicenter occurred in the Delta, or of magnitude 8 on the San Andreas or Hayward faults." Thus earthquakes were considered but not fully accounted for. While sometimes referred to as the PL 84-99 Ag standard, this standard actually applies to both agricultural and urban levees within the legal Delta. The standard adds a stability requirement to what is otherwise principally a geometric standard. It provides for a crown width of 16 feet, freeboard of 1.5 feet over the 100-year water surface elevation, a minimum waterside slope of 2-to-1, and landside slopes that vary as a function of the depth of peat and the height of the levee such that the static factor of safety on slope stability is not less than 1.25. Very approximately, the landslide slope can be 2-to-1 for levee heights no greater than 5 feet, can be 3-to-1 for levee heights no greater than 10 feet, can be 4-to-1 for levee heights no greater than 20 feet, and has to be 5-to-1 for levee heights of 25 feet or greater. Alternately, the minimum factor of safety can be achieved by construction of a landside toe berm. While this standard does not fully address earthquake loadings, the flatter slopes and/or landslide berms that are required for levees built over peat means that they are fundamentally less likely to suffer major distress as a result of earthquake loadings. This Delta-specific standard leads to the result that levees in the western and central Delta which overlie peat are likely to be less susceptible to damage in earthquakes than levees in the north and south Delta, which both overlie more sandy soils and tend to be composed of sandy soils and thus are more susceptible to liquefaction. While the Delta-specific PL 84-99 standard includes no specific guidelines on vegetation, it is assumed that the Corps national standards on levee vegetation, which basically ban all significant vegetation on both land and watersides, apply unless a specific variance from those standards is obtained. This question is currently the subject of a significant debate between the State of California and USACE, with the State arguing for the positive engineering and environmental benefits of vegetation on the waterside slopes of levees. The State's position is indicated by the proposed provisions for urban levees which are noted below.

Sacramento District (SPK)

While not directly applicable to Delta levees, the Geotechnical Levee Practice of the Sacramento District of USACE (designated SPK) has some relevance because it informs both the Urban and Non-Urban Levee Evaluation programs and the DWR Urban Levee Design Criteria that are presently being developed. This SPK Practice calls for a minimum crown width of 20 feet for main-line levees and minimum water and landside slopes of 3-to-1. Existing levees, with landside slopes as steep as 2-to-1, may be retained in rehabilitation projects if their historic performance has been satisfactory. This move to 3-to-1 slopes is driven by maintenance issues as much as slope stability and seepage issues. The practice also suggests minimum requirements for geotechnical investigations and analyses. Although it describes recommended standard practice, it also makes it clear (and this aspect is often overlooked) that the responsible engineers should use appropriate judgment as a function of site-specific conditions and experience.

Urban Levee Design Criteria (ULDC)

DWR was directed by SB 5 to develop appropriate standards for urban levees, and version four of the Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento–San Joaquin Valley was published in December 2010. These criteria are now being finalized as the

Urban Levee Design Criteria which will eventually become a State regulation. The ULDC is generally consistent with the SPK Practice and has the same geometric requirements. However, the ULDC goes much further in defining required practice in a number of other areas including seismic loadings, encroachments, penetrations and vegetation. With regard to vegetation, the draft ULDC language generally prohibits vegetation in accordance with the USACE national policy but allows woody vegetation on portions of the waterside slope and riverbank or berm for a newly constructed levee if a specially-designed waterside planting berm is added or the levee section is otherwise widened. In the case of the repair or improvement of existing levees, the draft ULDC language allows trees and other vegetation to be preserved over the long term if they provide important or critical habitat or erosion protection, soil reinforcement or sediment recruitment. In order to mitigate possible adverse effects of roots, where feasible the overall width of the levee should be widened landward by at least 15 feet or an effective root or seepage barrier shall be installed within the upper 10–15 feet below the levee crown. For other levees with pre-existing vegetation, the UDLC requires inspection and thinning in accordance with the Central Valley Flood System Improvement Framework. It is suggested that these provisions are generally applicable to Delta levees.

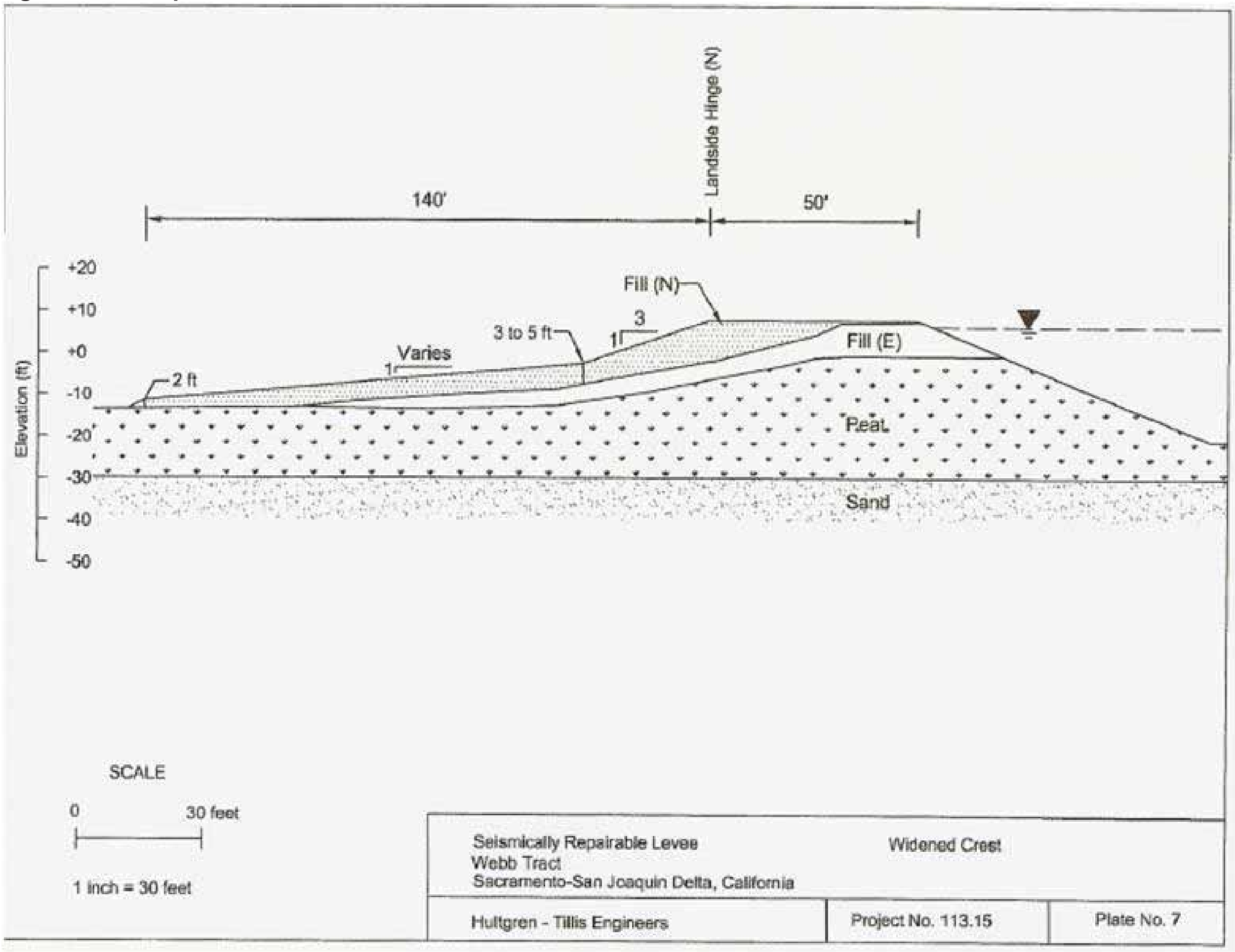
Proposed Core Delta Levees Standard

With the exception of the ULDC, which addresses design and/or quick repair of levees for 200-year return period earthquakes, none of the above standards explicitly address seismically-resistant design, or design for greater than 100-year water surface elevations and possible sea-level rise. The 1983 Delta Levees Investigation (see Section 3.3.1 below) did suggest that Delta levees should be designed for 300-year water surface elevations but that suggestion has not been included in subsequent standards or revisions. Although updated estimates of water surface elevations from the Central Valley Flood Protection Plan are still pending, it is commonly believed that water surface elevations in much of the Delta are strongly influenced by tides and that 300- or even 500-year water surface elevations are only a foot or two higher than 100-year elevations. Pyke (2011)[39] has suggested that an appropriate standard for the design of Delta levees might be to design for 500-year flood and earthquake loadings. Likely, adoption of the ULDC requirement for three feet of freeboard over the 100-year water surface elevation coupled with superior flood-fighting would effectively provide 500-year flood protection. Building to this standard would increase the cost marginally over the cost of complying with the Delta-specific PL 84-99 standard. Levees in the western and central Delta which overlie peat and meet the Delta-specific PL 84-99 standard might already meet this higher standard. As an example, the cross-section of a proposed seismically-resistant levee taken from a report by Hultgren-Tillis Engineers (HTE) for Reclamation District 2026 (Webb Tract)[40] is shown in Figure 16. Even when assuming that some liquefaction might occur both in the embankment and the foundation, this study indicates that deformations would be limited by the addition of a landslide buttress, as shown in the figure. This design was estimated to cost approximately $2 million per mile in 2009. HTE also looked at more elaborate designs which included either or both of a slurry trench wall or an internal drain, but those designs added no more than $5 million per mile to the incremental cost. By comparison, Suddeth et al. (2008)[41] cited a cost of $45 million per mile

[39] Pyke, R. (2011) Comments of the First Staff Draft of the Delta Plan. Delta Stewardship Council, February, 2011. http://deltacouncil.ca.gov/public-comments/read/143?page=1.
[40] Hultgren-Tillis Engineers, Geotechnical Evaluation, Seismically Repairable Levee, Webb Tract, Report to Reclamation District 2026, December 2009.
[41] Suddeth, R., J. Mount, and J. Lund (2008), "Levee Decisions and Sustainability for the Sacramento-San Joaquin Delta," Appendix B to *Comparing Futures for the Sacramento-San Joaquin Delta*, Public Policy Institute of California, San Francisco, CA, August.

from the DRMS Preliminary Strategies Report. That figure is clearly incorrect and appears to have been intended to apply to a new embankment with a 50-foot wide crest width which would protect the BNSF railroad and the Mokelumne aqueduct. As mentioned below, the DRMS Phase 2 report also includes a figure of $38 million per mile, but that is for a setback levee in connection with widening and hardening a single conveyance path through the Delta.

Figure 16 Example Delta Levee Cross Section



A key feature of the design shown in Figure 16 is the wide crest. Some reclamation districts are already planning for or are constructing improved levees with a 22-foot crown width, adequate for a two-lane, sealed road. Wider crests not only provide a more robust levee, but also allow for more efficient emergency response. Levees with wider crests are also the most economical way to provide for possible sea-level rise. While it is the policy of the State to plan for 55 inches of sea-level rise by the year 2100, the probability of that magnitude of sea-level rise is actually very small. While it is not cost-effective or rational to construct levees to those elevations today, the provision of a wider crest today has two benefits: providing a more robust levee immediately, allowing more room for flood-fighting or emergency response following earthquakes, and allowing a choice of methods for raising the crest elevation in the event of actual sea-level rise. In addition, the provision of a wider crest also allows for retaining or planting vegetation on the waterside of the levee in accordance with the ULDC guidelines. Such planting should be an essential component of any comprehensive plan to repair the Delta ecosystem. Local widening of these levees would also allow for the construction of new recreational and tourist facilities out of the flood plain.

3.3 Previous Studies of Delta Levees

3.3.1 Delta Levees Investigation, DWR Bulletin 192-82

In 1976 the legislature directed DWR to prepare a plan for the preservation of the Delta levees. After a joint study with USACE, a definitive plan for the improvement of all Delta levees was completed six years later and published as Bulletin 192-82,[42] which recommended a levee standard similar to the current Delta-specific PL 84-99 standard. The forward to the report, signed by Ronald Robie, then Director of DWR, states in part:

> *Now is the time for a decision. The most significant element in a decision on what action to take is how much can we afford and who will pay? These questions can only be answered by the Legislature the local landowners, and the Congress.*
>
> *There is a danger that taking a short-term view of Delta flooding problems will merely pass the tough issues on to the next generation. Short-run economic decisions may serve to subsidize private interest as the expense of the general public. The great challenge for the Delta is to find an equitable way of financing a very uncertain long-term future. The political process is the traditional arena for handling these kinds of issues and is the right forum for the next step in Delta deliberations.*
>
> *These policy issues must be addressed today. In the event the Legislature determines that a major responsibility for levee restoration should fall upon the State, a bond issue or other form of capital financing must be developed and approved by the people.*

At that time, it was estimated that improving all levees to the proposed Bulletin 192-82 standard would cost $930 million if implemented immediately. However, although funding of the subventions program continued at a relatively low level, financing was never put in place to implement this more significant levee-improvement plan.

3.3.2 CALFED Levee System Integrity Program

A similar study, called the CALFED Levee System Integrity Program, was subsequently conducted as part of the CALFED program.[43] The executive summary of the Levee System Integrity Program Plan, dated July 2000, contains the following statements:

> *Many Delta levees do not provide a level of flood protection commensurate with the high value of beneficial uses they protect. As mandated by the California State legislature and adopted by CALFED, the physical characteristics of the Delta should be preserved essentially in their present form. This is necessary to protect the beneficial uses of the Delta. The key to preserving the Delta's physical characteristics and to achieving CALFED's objectives is the levee system. Over the next 30 years CALFED will invest billions of dollars in the Delta. The levees must protect this investment.*
>
> *The existing levee program (*the subventions program*) was intended to improve Delta levees up to the California/Federal Emergency Management Agency (FEMA) Hazard*

[42] Delta Levees Investigation, Department of Water Resources, Bulletin 192-82, December 1982
[43] http://calwater.ca.gov/content/Documents/library/305-1.pdf

Mitigation Plan (HMP) Standard. As of January 1998, 36 of 62 (58%) Delta islands and tracts were in compliance with the HMP standard. This has resulted in a significant improvement in the ability to protect the beneficial uses of the Delta. However, as CALFED invests in the Delta, more is at risk. Therefore CALFED has chosen to improve the Delta levees to a higher level.

The CALFED Levee program will institute a program that is cost-shared among the beneficial users to reconstruct Delta levees to the Corps' PL 84-99 Delta Specific Standard. This action will increase levee reliability and reduce emergency repair costs. In addition, levee districts meeting this standard are eligible for federal emergency assistance under PL 84-99.

The plan to improve the levees to the PL 84-99 standard was not new. It had been recommended in Bulletin 192-82. The CALFED study estimated that the cost of improving all the Delta levees to the PL 84-99 standard ranged from $367 million to $1.051 billion, not inconsistent with the $930 million estimated in 1982. But again, no funding materialized until in 2006, in the wake of the Paterno Decision, Propositions 84 and 1E provided for up to $775 million to be spent on Delta levees. The slow pace of disbursement of these funds is discussed subsequently but, in effect, this was the funding that had been recommended first by Bulletin 182-92 and then by CALFED.

The CALFED plan also discussed the fact that funding for levee work is insufficient, inconsistent, and often delayed; that dredging is required to increase channel capacity and to provide material for levee reconstruction, habitat restoration and creation, and subsidence control, but that dredging had been curtailed due to regulatory constraints, causing dredging equipment and trained manpower to leave the Delta; that emergency response capabilities need to be continuously refined and funding increased; that levee reconstruction and maintenance sometimes conflicts with management of terrestrial and aquatic habitat resources; that obtaining permits for levee work can sometimes be difficult and time consuming; and that while subsidence may adversely affect levee integrity, this can be corrected.

With respect to seismic loadings the plan said:

Some CALFED stakeholders are concerned that earthquakes may pose a catastrophic threat to Delta levees, that seismic forces could cause multiple levee failures in a short time, and that such a catastrophe could overwhelm the current emergency response system.

CALFED agrees that earthquakes pose a potential threat. In addition, Delta levees are at risk from floods, seepage, subsidence, and other threats. To address this concern, CALFED has begun a risk assessment to quantify these risks and to develop a risk management strategy.

The plan listed 10 possible risk management options which included improving emergency response capabilities and reducing the fragility of the levees and indicated that the final Risk Management Plan might include a combination of the 10 options.

3.3.3 Delta Risk Management Strategy

AB 1200 (authored by John Laird, the current California Secretary for Natural Resources) required that DWR evaluate the potential impacts on water supplies derived from the Delta based on 50-,100-, and 200-year projections for each of the following possible impacts: subsidence, earthquakes, floods, climate change and sea-level rise, or a combination of these impacts. This legislation had the effect of changing the CALFED recommended study into what became the Delta Risk Management Strategy (DRMS) and the Risk Management Plan envisioned by CALFED has never been completed.

DRMS was conducted for the Department of Water Resources (DWR) by a team of consultants led by URS Corporation and Jack R. Benjamin & Associates. The study reportedly cost $6 million. Originally, the study was intended to have two phases. The first phase was an assessment of the then-current (2005) risks to the Delta and the second phase was to have been a projection of future risks assuming various scenarios. The Phase One draft generated a great volume of critical comments, and the effort required to respond to them cut into the available funding for Phase 2. The Phase 1 Risk Analysis Report was released in 2009, but the report on the modified Phase 2 study has only just been released. The stated purpose of the study, the participants, and a summary of the Phase 1 results are provided in the Executive Summary prepared by DWR, available on the department's website.[44]

The DRMS Phase One report was extensively reviewed, including a review by an independent review panel (IRP) assembled by the Cal-Fed Science Program. The reviews were generally critical of the study. The IRP review[45] concluded that "the revised DRMS Phase 1 report is now appropriate for use in DRMS Phase 2 and serves as a useful tool to inform policymakers and others concerning possible resource allocations and strategies for addressing risks in the Delta." But the IRP expressed concerns:

> "*This conclusion, however, is subject to some important caveats. First, the IRP cautions users of this revised DRMS Phase 1 report that future estimates of consequences must be viewed as projections that can provide relative indicators of directions of effects, not predictions to be interpreted literally. Second, anyone using the results of the DRMS scenarios must be aware that ecosystem effects are not fully captured in the analysis....*"

Although the DRMS developed a good framework for assessing risks to the Delta levees, the effort had data gaps that were never filled, as acknowledged in the note on page 1-1 of the report. Gaps such of these in data and knowledge tend to drive the estimates of fragilities down, and the risks up.[46] Since improvements have been made to some Delta levees under the subventions program since 2005, the DRMS results are out of date. The numerical results from the DRMS Phase 1 report, however, are widely quoted, painting a more pessimistic picture of the Delta levee system than perhaps is warranted.

The modified DRMS Phase 2 study focuses on Risk Reduction as opposed to Risk Analysis and evaluates the costs and benefits of four alternative scenarios for levee improvement and conveyance. However, in the words of its authors:

> *Similar to the Delta Risk Management Strategy (DRMS) Phase 1 Risk Analysis Report (URS/JBA 2007h), the DRMS Phase 2 Risk Reduction Report was carried out for the*

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[44] http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/
[45] The independent review panel (IRP) comments on the DRMS Phase I draft report are published on the State's archived CALFED website: http://calwater.ca.gov/science/drms/drms_irp.html
[46] Use of decades-old data are evident in some of the erroneous failure probabilities, such as the over 7 percent annual failure probability attached to the Brookside subdivision in Stockton, which in reality has high quality levees that were improved as part of the subdivision development.

> *most part using existing information (data and analyses). The Phase 2 schedule did not afford the opportunity to conduct field studies, laboratory tests, or research investigations.*

Section 20 of the report then lists a number of assumptions and limitations, and concludes:

> *The complexity of the issues in the Delta and the limited time available to undertake the Phase 2 effort means that additional scenarios that could not be developed in this phase will require consideration. Further, the performance of sensitivity analyses of the scenarios themselves would be valuable to assess the importance of the major components of the scenarios on the overall risk reduction benefits. Other ongoing agency initiatives will likely require consideration of additional scenarios.*

Nonetheless, the key findings relative to the two types of levee upgrades that were considered (and are listed below) are not inconsistent with the present study.

- *Most of the Delta levees already meet the HMP standard.*
- *Some of the levees in the central Delta (project levees) already meet the PL 84-99 standards.*
- *The cost of upgrading 764 miles of selected non-project levees (levees that do not meet PL 84-99 standards) in the central Delta to PL 84-99 standards is about $1.2 billion.*
- *The cost of upgrading 187 miles of selected levees around urban centers to UPL standards is $750 million.*
- *Upgrading levees to meet the target standards will reduce the probability of failure due to flooding. However, these upgrades do not guarantee that the upgraded levees, particularly those upgraded to PL 84-99 standards, will not fail during a 100-year flood. The 1.5 feet of freeboard is insufficient for regions subject to high winds during floods.*
- *Upgrading levees to meet the PL 84-99 and UPL standards does not reduce the seismic risk of levee failure.*

Elsewhere the report says that “upgrading the levees to the Pl 84-99 and UPL standards would <u>do little</u> to reduce the risk of failure under seismic loading.” However, curiously, the report says nothing about what it would take to further upgrade the critical levees so that they are more robust under seismic loadings. Rather Scenario 1, which is entitled “Improved Levees,” assumes that the levees are not robust under seismic loadings and estimates the cost of hardening the state highways that cross the Delta, by putting them on piles like the elevated section of the Yolo Causeway, and the BNSF railway and the Mokelumne Aqueducts, either by building seismically-resistant embankments with a 50-foot crown width on either side of the existing railway and aqueducts, or by placing the railway and aqueducts on a single embankment with a 180-foot crown width. The cost of these hardening measures was estimated to be $6.1 billion for the highways and $3.3–3.9 billion for the infrastructure corridor. Adding these figures to the cost of the planned levee improvements resulted in a stated total capital cost for Scenario 1 of $10.4 billion, as reported in Table 1 of the executive summary. Within the estimate for the hardened infrastructure corridor are the figures of $45.2 million per miles for the 50-foot crown width embankment and $94.6 million per mile for the 150-foot crown width embankment.

Likewise Scenario 2, which is titled “Through Delta Conveyance (Armored Pathway),” ignores the possibility of a general upgrade to levees that are more robust under seismic loading and instead assumes the construction of 115 miles of new seismically-resistant setback levees, at a cost of $38 million per mile. The total capital cost given in Section Eight of the report for a

15,000 cfs through Delta facility is $5.7 billion, although in Table 1 of the executive summary this figure mysteriously jumped to $15.6 billion.

This study concludes that the core Delta levees can be made robust under seismic loadings for a total of $1–2 billion. If such a scenario had been considered in the DRMS Phase 2 study, it would likely have a lower cost-to-benefit ratio than the alternatives that were considered.

3.3.4 Delta Islands and Levees Feasibility Study

Meanwhile, the successor to the Bulletin 192-82 and CALFED studies is the USACE Delta Islands and Levees Feasibility Study, which is an on-going effort in collaboration with DWR.[47] The proposed total USACE budget for this study is $6 million and DWR is contributing the DRMS study, which also cost $6 million, as their contribution. The official description of the study is:

> *This feasibility study is USACE's mechanism to participate in a cost-shared solution to a variety of water resources needs for which we have the authority. Results of state planning efforts will be used to help define problems, opportunities, and specific planning objectives. The feasibility study will address ecosystem restoration and flood risk management, and may also investigate related issues such as water quality and water supply. USACE and DWR signed a Feasibility Cost Sharing Agreement (FCSA) in May 2006.*

Little progress has been made to date. Thus, three joint State-Federal efforts over the last 30 years have had some positive impact in that they have generated the concept of improving Delta levees to the PL 84-99 standard and have supported the continuation of the funding that is provided under the subventions program and the additional funding that was authorized under Propositions 84 and 1E, but they have not yet led to a strategy which will make the Delta sustainable longer-term facing the hazards due to floods, earthquakes, and possible sea-level rise.

4 Risk-Reduction Strategies

There are three basic approaches to addressing the risks posed to the Delta levees by floods and earthquakes. One is to simply make the up-front investment to improve the existing levees so that they are more robust; a second is to make the preparations in advance for improved flood-fighting and/or emergency repairs following an earthquake so that breaches do not occur; the third is to make preparations in advance for repair of breaches and the draining of any flooded islands if breaches do occur so that the consequences are minimized. These three approaches are discussed in more detail in the following sections.

4.1 Improve the robustness of the existing levees

This is the standard approach to reducing risk: invest up-front in making everything more robust. Without detailed analysis, it seems clear that essentially all Delta levees should be improved to the Delta-specific PL 84-99 standard. Unfortunately, Draft 3 of the "Framework for DWR Investments in Delta Integrated Flood Management," a document that was only released for public comment on July 15, 2011, but had already been forwarded to the Delta Stewardship Council, states or implies that the HMP "standard" provides an adequate basic level of protection against floods and earthquakes for Delta levees. The exact language of the draft Framework is:

[47] http://www.spk.usace.army.mil/projects/civil/Delta/News.html

As funding is available, DWR intends to cooperate with local public agencies to develop local plans to improve levees within the Delta levee network to at least the HMP standard. Some levees may warrant additional investment to provide a level of protection beyond the HMP standard, but these projects likely would need to be justified based on one of the other categories of benefit described in this section.

On the basis of this language, the 4th staff draft of the Delta Plan, in Table 7-1, indicates that levees built only to the HMP "standard" are acceptable for protection of agricultural lands. However, the HMP "standard" is not an engineering standard. It is a minimum configuration agreed to by the state and federal governments for the purpose of defining a serious levee in order to protect the federal government from facing possible exposure to the cost of repairing levees that are height limited or not seriously being maintained. Since 1982 the minimum standard for engineered levees in the Delta has been the Delta-specific standard that was recommended in Bulletin 192-82 and subsequently adopted by the Corps of Engineers as the PL 84-99 standard for Delta levees. This Delta-specific PL 84-99 standard was also adopted in the CalFed Levee System Integrity Program Plan as the minimum standard for Delta levees. That plan specifically said:

The CALFED Levee program will institute a program that is cost-shared among the beneficial users to reconstruct Delta levees to the Corps' PL 84-99 Delta Specific Standard. This action will increase levee reliability and reduce emergency repair costs. In addition, levee districts meeting this standard are eligible for federal emergency assistance under PL 84-99.

The draft Framework and the draft Delta Plan would roll back 30 years of joint State-Federal co-operation without sufficient justification.

While Figure 14 indicates that there are few if any islands in the Delta that are in purely agricultural use without infrastructure or other beneficial uses, flooding of even a hypothetical purely agricultural island has adverse impacts on the adjacent islands in terms of both wave action and enhanced seepage as well as on Delta-wide water quality in addition to the agricultural losses, and, as noted by both Healey and Mount (2007)[48] and Suddeth et al. (2011)[49], the ecological benefits of additional flooded islands are uncertain. The call in the draft Framework for justification of improvements beyond the HMP "standard" could easily be satisfied, but doing so would create additional delays, paperwork, and expense. Moreover, because improvement of Delta levees to the Delta-specific PL 84-99 standard has been the announced policy of the State, and because funding adequate to achieve this goal was approved by the voters in Propositions 84 and 1E, it would seem that failure of the State to conscientiously and uniformly pursue this goal exposes the State to significant Paterno, that is, inverse condemnation and liability.

If the marginal cost of making additional improvements to further reduce the risk due to floods, earthquakes, and sea-level rise is tolerable, then those improvements should likely be made in accordance with a new Delta levees standard. These levees would not necessarily be

[48] Healey, M., and J. Mount (2007), Delta Levees and Ecosystem Function, Memorandum to John Kirlin, Executive Director of Delta Vision, November 2007.

[49] Suddeth. R. (2011), Policy Implications of Permanently Flooded Islands in the Sacramento-San Joaquin Delta, UC Davis Center for Watershed Sciences, http://watershed.ucdavis.edu/pdf/Suddeth_Policy_Implications_of_Flooded_Islands_080110.pdf

“earthquake proof,” but they would reduce the probability of single or multiple failures from any cause to quite low levels, in the order of 1 percent per year or less. Levees improved to this new Delta standard would also provide a greater freeboard and wider crests allowing two-way traffic, which will enhance emergency response. They would also allow emergency borrowing of materials from landside toe-berms to restore the crests of any levees that slump as a result of earthquakes. The argument for making this additional investment is pretty straight-forward: even the Delta-specific PL 84-99 standard does not necessarily provide adequate protection from more extreme floods and earthquakes and does not provide a basis for adaption should sea level rise at an enhanced rate. Assuming a cost of $2–3 million per mile for 300 to 600 miles of levees, the $1–2 billion minimum investment that would be required to improve the core levees to this higher standard is small compared to the value of the land that they protect, the recreational benefits that they provide, and the value of the infrastructure that crosses the Delta. Some idea of the value of that infrastructure can be gained from the estimate in DRMS Phase 2 that it would cost in the order of $10 billion to harden the state highways, the BNSF railway, and the Mokelumne Aqueduct to make them seismically-resistant in the absence of seismically-robust levees. Thus relative benefit to cost ratio of further improving the levees is at least five times as great as the alternative, assuming that the benefits are equal, which they are not because the seismically-robust levees would protect much more than just this selected infrastructure. Further seismically-robust levees would protect the existing through-Delta conveyance paths and, while this would not solve all the conveyance and storage issues facing the State, it is more than five times less expensive that the presently-proposed BDCP Isolated Conveyance, which does not solve all those conveyance and storage issues in any case. The real issue here is not whether to move to this higher standard for core levees, but just how high it should be, and just how much should be invested in levee improvements as opposed to better emergency preparedness, as discussed in the following section. For example, if, as opposed to spending $2 million per mile on further improvements of the kind shown in Figure 16, an internal drain was provided as suggested in one of Hultgren-Tillis Engineers’ more expensive alternatives, at a cost of say $5 million per mile, would the increased cost be justified by the reduction in risk, assuming the same level of emergency preparedness? Or, could that lower level of risk be achieved more cheaply by making a greater investment in emergency preparedness? Notwithstanding all the difficulties that are noted in Appendix D of conducting complete and accurate risk analyses, which also apply to life-cycle cost benefit analyses, these are questions that may be deserving of further study.

This discussion assumes that the current levee system remains pretty much as it is, but it is not intended to suggest that small islands such as Fay, Dead Horse, and Quimby necessarily have to remain in agricultural use, that some efficiency might not be obtained by combining several islands into polders, or that intelligent combined flood risk management/ecosystem restoration projects such as the Lower San Joaquin River Flood Bypass[50] do not have merit. There may also be a valid argument for modifying the existing Delta channels to provide greater or more varied flows and retention times, but that involves various trade-offs and requires evaluation in advanced hydrodynamic and fluvial geomorphology studies of a kind that have not yet been conducted for the Delta.

[50] Lower San Joaquin River Flood Bypass Proposal, South Delta Levee Protection and Channel Maintenance Authority, Submitted to California Department of Water Resources, March, 2011

4.2 Improve flood-fighting and emergency repairs after earthquakes

As discussed above and in Appendix D, few if any levee failures actually occur without warning. There is normally a few days to a few weeks warning of flood events. Earthquakes occur without warning, but the consequences of even a moderate-to-large earthquake that affects the Delta are more likely to be some slumping rather than immediate breaches. Even sunny-day failures may be preceded by signs of trouble. Since levee failures typically come after days or weeks of initial warnings, it is clearly cost-effective to invest in emergency preparedness and modern investigative techniques to head off failures before they occur.

Below are some of the measures suggested to improve this kind of emergency response.

- Create stockpiles of the newer types of temporary means for raising levees such as "Aquatubes" or "Aquafences." These allow for temporary increases in the levee height when a particularly severe flood threatens or after an earthquake. These devices can quickly raise the crest of a levee over much greater lengths than can be accomplished with conventional sandbags.
- Create stockpiles of appropriate materials to deal with enhanced seepage and develop the means to transport them quickly to any point in the Delta.
- Set in place plans and procedures for emergency repairs to levees following an earthquake. This might include borrowing from landside toe-berms as suggested above.
- Use newer technology, such as that developed at the University of Texas at Austin by Professor Kenneth Stokoe for monitoring highway and airfield pavements, to conduct periodic inspections of the levees. This technique senses small changes in the levee, such as those caused by rodent burrowing, and thus flags locations that require more detailed inspection.
- Install simple fiber-optic cables at the toes of levees as suggest by Professor Jason de Jong of UC Davis in order to sense deformations. Again, this technique flags locations that require more detailed inspection and, in the event of an earthquake or terrorist activity, would immediately identify trouble spots for emergency managers and national security personnel.

Improved federal, State, county, and community coordination is equally important in preventing failures. Notwithstanding improvements in coordination that are currently being worked on, the suggestion made elsewhere that responsibility for emergency-response planning and levee improvements be turned over to a Delta-region authority with an appropriate funding base appears to have great merit.

4.3 Improve immediate response to breaches and repair of breaches and draining of flooded islands

In general, emergency response following a breach involves two elements. The first of these is very immediate and involves controlling the spread of flood waters, evacuating threatened people and livestock, and minimizing damage. In the riverine environment this might involve blocking freeway underpasses or otherwise reinforcing secondary levees and making relief cuts through levees to drain floodwaters back into the river system at a lower point on the river. To be effective, these actions require detailed emergency planning and preparation. However, while this kind of planning and preparation should be made for the Delta islands, there is likely little that can be done in this regard on most of the more deeply-subsided islands following a breach. It is difficult or impossible to reduce or stop the flow of water until the island is flooded and water levels equalize. Once that has happened, the breach can be repaired and the island pumped out. However, as illustrated by the repair of the 2004 Upper Jones Tract failure, unnecessary delays and expense can occur unless the repair of the breach is planned and executed properly. In that case larger rocks were used to initially plug the breach but there were insufficient fines to limit continuing seepage to an acceptable rate. That resulted in construction of a waterside berm with provision for the planting vegetation on a bench in part as mitigation for encroachment into the channel, as may be seen in Figure B7 in Appendix B. Thus forward planning and stockpiling of suitable materials for repair of levee breaches is very desirable. In the absence of a one-stop permitting mechanism, it also seems very desirable that this forward planning includes establishment of a fast-track procedure for acquiring any necessary permits or authorizations. Speedy repair of breaches and pumping out of flooded islands not only minimizes damage and losses on the island in question but also the losses that occur as a result of enhanced seepage into adjacent islands.

4.4 Current planning efforts

4.4.1 High-Level Coordination

In response to SB 27, the California Emergency Management Agency, Cal EMA, organized a Delta Multi-Hazard Coordination Task Force. Since funding was never provided by the legislature, this task force operated on limited funding to develop a draft report that recommends that $11.5 million be allocated for various planning studies and that a permanent emergency response fund of $50-150 million be established. Some of the recommended planning efforts appear to overlap with DWR-USACE activities that are already under way, but the final Task Force report has not yet been released.

4.4.2 DWR Emergency Planning

The current DWR studies were initiated by the Metropolitan Water District of Southern California (MWD) which, commencing in February 2006, undertook a study of two options for minimizing the interruption of exports resulting from a hypothetical 50 levee breaches/20 flooded islands scenario. The pre-event scenario involved advance construction of levee and river-flow barriers to block saltwater from entering the south Delta in a major emergency. It was estimated to cost $330-485 million. The post-event strategy allowed saltwater to enter the entire Delta, followed by the creation of an emergency freshwater pathway to the export pumps. The cost estimate for this strategy was about $50 million for pre-positioning of materials, with an ultimate cost of perhaps $200 million. MWD then elected in April 2007 to pursue the second alternative in association with the State Water Contractors and DWR using funds from propositions 84 and 1E to the maximum extent possible.

By January 2008 DWR was reporting on progress on the adopted strategy. At that time, contracts had been signed for the delivery of 240,000 tons of rock to three stockpiles in Rio Vista, Hood, and the Port of Stockton by June 2008. A planned second phase would have increased the quantity of rock at each location and added additional “breach closure materials.”

That work has now apparently been subsumed into the development of a broader DWR plan which is intended to guide DWR’s activities during an emergency. This plan includes three components:

1. In association with USACE, development of a GIS-based flood contingency maps and associated data.

2. Development of strategies for minimizing the delay in restoring fresh water to the export pumps. This included advanced modeling of salinity intrusion and risk assessments. Although no results have been officially reported, it is understood that these studies suggest that the Delta flushes out more rapidly than had previously been expected, and that exports could be resumed in a maximum of six months, but more likely in a shorter period, even if multiple islands have been flooded.
3. Definition of the roles and responsibilities of DWR emergency response personnel and coordination with other agencies.

There is also some work being done on further development and implementation of emergency response facilities in the Delta for the 50 breaches/20 flooded islands scenario, but the details of this are unclear. Some concern has also been expressed that the rock that has already been stockpiled is more suitable for creating river barriers than it is for repairing breaches.

4.4.3 County-Level Planning

Work is continuing on various county emergency response plans but these are more oriented to immediate response and public safety than to repair of levee breaches and de-watering of flooded islands. Nonetheless, there are many elements of these plans, such as the flood maps and guide developed by San Joaquin County[51] that could be usefully extended to cover the entire Delta. However, rather than having individual county plans, it would seem to be desirable to have a single integrated Delta-wide emergency response plan that identifies only as sub-sets the actions that need to be taken by the individual counties.

4.5 Summary

While some progress is being made on all three approaches to risk reduction, much of the DWR effort appears to be directed to the third approach, responding to failures after they have happened, instead of preventing them. While the DWR doomsday scenario is turning out to be less of a risk than initially thought and the current round of planning should be completed, much more emphasis should be given to the issues raised by Baldwin (2011),[52] most notably that a regional emergency response agency is required, and that the regional emergency response agency should place much more emphasis on preparation for flood-fighting and emergency response following earthquakes, as discussed herein in Section 4.2.

5 Levee Improvement Strategies and Funding

Commencing in 1973 funding has been provided by the State of California to assist the Delta reclamation districts under two programs.

The Delta Levees Maintenance Subventions Program provides financial assistance to local levee-maintaining agencies for the maintenance and rehabilitation of non-project levees in the Delta. It is authorized in the California Water Code, Sections 12980 through 12995. It has been in effect since passage of the Way Bill in 1973, which has since been modified periodically by legislation. The intent of the legislation, as stated in the Water Code, is to preserve the Delta as much as it exists at the present time. A summary of expenditures under the subventions program is included as Table 3.[53] The amounts for FY 2008-9 and 2009-10 are still in the

[51] http://sjmap.org/oesmg/gfcm/Flood_Map_Guide_Final_6-1-10.pdf
[52] Baldwin, R. (2011), San Joaquin County Comments on the First Staff Draft of the Delta Plan, http://deltacouncil.ca.gov/public-comments/read/143?page=1
[53] Provided by DWR – also included in the DWR Technical Memorandum

pipeline and have not actually been expended. Excluding these years, the State has provided $126 million against a local share of $110 million for a total of $236 million.

Table 3 Delta Levee Subventions Maintenance Program State & Local Cost Share 1973-2010

STATE							
Fiscal	Maintenance	Priority 1	Priority2	Priority 3	Total	Local	**Sub-**
Years	Reimburs.				Reimburs.	Share	**Total**
	(1)	(2)	(3)	(3)			
	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	**$1,000**
1973-74	200				200	272	472
1974-75	175				175	483	658
1975-76	-				-	-	-
1976-77	190				190	395	585
1977-78	175				175	486	661
1978-79	175				175	323	498
1979-80	-				-	-	-
1980-81	-				-	-	-
1981-82	1,421				1,421	2,091	3512
1982-83	1,334				1,334	1,929	3263
1983-84	1,384				1,384	3,803	5187
1984-85	1,817				1,817	2,279	4096
1985-86	1,335				1,335	1,628	2963
1986-87	1,736				1,736	2,097	3833
1987-88	1,882				1,882	1,501	3383
1988-89	1,295	3,705			5,000	4,371	9371
1989-90	1,913	3,407			5,320	8,668	13988
1990-91	1,610	3,689			5,299	8,404	13703
1991-92	2,266	159			2,425	10,449	12874
1992-93	1,823				1,823	4,244	6067
1993-94	1,774	2,916	376	15	5,081	2,070	7151
1994-95	2,371	2,770			5,141	2,233	7374
1995-96	1,449	2,097			3,546	1,602	5148
1996-97	1,758	1,790			3,548	2,158	5706
1997-98	4,432	2,647			7,079	2,974	10053
1998-99	3,412	1,738			5,150	2,341	7491
1999-00	3,085	3,194	58		6,337	2,715	9052
2000-01	4,954	3,053	55		8,062	3,371	11433
2001-02	3,777	1,784			5,561	2,515	8076
2002-03	3,554	1,446			5,000	4,666	9666
2003-04	4,029	1,996			6,025	6,102	12127
2004-05	4,698	1,227			5,925	6,476	12401
2005-06	5,364	358			5,722	4,220	9942
2006-07	4,485	1,505			5,990	6,647	12637
2007-08	5,645	8,503	2,148		16,296	6,210	22506
2008-09	6,810	4,515	545		11,870	4,799	16669
2009-10	7,254	2,131	41		9,426	3880	13306
	89,582	**54,630**	**3,223**	**15**	**147,450**	**118,402**	**265,852**

(1) Excess maintenance over the maintenance cap and DFG costs are included in the maintenance.
(2) Priority 1 includes HMP and Bulletin 192-82 work.
(3) Priority 2 is priority 1 excess cost over $100,000 per mile cap. Priority 3 is land use changes

The Delta Levees Special Flood Control Projects provides financial assistance to local levee-maintaining agencies for rehabilitation of levees in the Delta. The program was established by the California Legislature under SB 34, SB 1065, and AB 360. The special projects program is authorized in the California Water Code, Sections 12300 through 12314. This program initially focused on flood-control projects and related habitat projects for eight western Delta Islands—Bethel, Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb Islands—and for the Towns of Thornton and Walnut Grove; in 1996 it was extended to the rest of the Delta. A summary of expenditures under the special projects program is included as Table 4.[54] The funds for FY 2008-9 and 2009-10 have not yet been expended. The figure for FY 2009-10 includes $35 million specially designated by the legislature for improvements to the five islands that protect the Mokelumne Aqueduct. The expenditures for FY 2007-8, 2008-9, and 2009-10

[54] Provided by DWR and also included the DWR Technical Memorandum

are larger than in previous years because of bond funding approved by the voters in Propositions 84[55] and 1E.[56] Through FY 2007-08, a total of $115 million had been expended through the special projects program.

The funds that are in the immediate pipeline include the $21 million from the State and $9 million local share for the subventions program and special project funding of $22 million for FY 2008-9 and $100 million for FY 2009-10, for a total of $152 million plus from State and local sources, plus an additional $195 million from USACE through the CALFED Levee Stability Program. The USACE funding was authorized by the CALFED Bay Delta Authorization Act of 2004 which provided for USACE participation in the then CALFED program.

Table 4 Delta Levee Program Special Projects State Expenditure 1989-2010

Fiscal Year	Planning & Engineering	Levee Construction	Habitat Enhancement	Total Expenditures
1989-1990	$15,000	$0	$0	$15,000
1990-1991	$5,210,000	$810,000	$0	$6,020,000
1991-1992	$709,400	$4,085,000	$0	$4,794,400
1992-1993	$668,500	$4,148,000	$0	$4,816,500
1993-1994	$140,000	$6,318,054	$0	$6,458,054
1994-1995	$300,505	$1,896,518	$0	$2,197,023
1995-1996	$30,000	$1,419,370	$0	$1,449,370
1996-1997	$513,618	$4,117,720	$0	$4,631,338
1997-1998	$609	$3,201,434	$0	$3,202,043
1998-1999	$0	$2,233,787	$4,035,000	$6,268,787
1999-2000	$80,555	$1,994,673	$4,009,134	$6,084,362
2000-2001	$199,613	$4,183,526	$3,837,381	$8,220,520
2001-2002	$0	$1,333,548	$1,138,797	$2,472,345
2002-2003	$800,985	$6,645,234	$6,961,843	$14,408,062
2003-2004	$95,979	$704,381	$1,118,243	$1,918,603
2004-2005	$188,044	$2,408,507	$972,500	$3,569,051
2005-2006	$553,989	$8,510,163	$446,193	$9,510,345
2006-2007	$922,127	$8,209,557	$59,500	$9,191,184
2007-2008	$1,606,681	$18,449,127	$144,000	$20,199,808
2008-2009	$4,115,986	$18,608,588	$0	$22,724,574
2009-2010	$2,346,311	$91,274,764	$6,117,538	$99,738,613
Totals:	**$18,497,902**	**$190,551,951**	**$28,840,129**	**$237,889,982**
Note: Funds for projects in FY 2008-2009 and FY 2009-2010 have been encumbered but in most cases have yet to be released due to recent, state-wide budgetary uncertainty.				

55 The Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006 (Proposition 84) authorizes $5.388 billion in general obligation bonds to fund safe drinking water, water quality and supply, flood control, waterway and natural resource protection, water pollution and contamination control, state and local park improvements, public access to natural resources, and water conservation efforts.

56 The Disaster Preparedness and Flood Protection Bond Act of 2006 (Proposition 1E) authorizes $4.09 billion in general obligation bonds to rebuild and repair California's most vulnerable flood-control structures to protect homes and prevent loss of life from flood-related disasters, including levee failures, flash floods, and mudslides and to protect California's drinking water supply system by rebuilding Delta levees that are vulnerable to earthquakes and storms. Proposition 84 enhances these efforts with an additional $800 million for flood-control projects.

The total investment in Delta levees since these programs began will be $698 million plus once the funding in the pipeline is expended. The fact that $351 million has been spent to date is already reflected in the generally improved condition of the levees. Also, because levees tend to fail at their weakest point, such as where they were constructed over old sloughs, many levees have already failed and then been repaired and improved at their weakest point, with the result that the present levee system is more robust than it was before the breaches. Also, concurrent with the cessation of dredging, there has been increased placement of rock rip-rap on the water side of the levees. Taken together, these three observations mean that historic data on the rate of levee breaches is no longer relevant, and out-of-date data compiled on the previously weaker system should not be repeated in current reports and discussions.

Table 4-1 of the DWR Technical Memorandum provides a breakdown of the funds appropriated for expenditure in the Delta from Propositions 84 and 1E. These funds total $615 million. Table 4-2 of the DWR Technical memorandum provides a breakdown of both the funds committed and the funds expended to February 2010. A total of $293 million had been committed to the subventions and special projects programs and $70 million had actually been expended at that point. The total funds committed amounted to $492 million and the total funds expended amount to $166 million, so that significant funds have been committed or expended for other purposes which include contracts, program delivery, emergency, the urban and non-urban levee evaluation programs, the Sacramento bank restoration program, and bond servicing costs. Approximately $123 million remain uncommitted.

Improvement of Delta levees from at or about the HMP standard to the Delta-specific PL 84-88 standard costs in the order of $1–2 million per mile,[57] the biggest variable being whether suitable borrow material is available on-island or whether it has to be trucked or barged from adjacent islands. With the funds that are in the immediate pipeline plus the remaining bond funds, all the core Delta levees should be improved so that they are at or about the Delta-specific PL 84-99 standard. Indeed, if expenditure of the bond funds had not been delayed by State spending freezes and other issues, this standard could have been generally met already. Continuing funding may still be necessary to take care of unexpected settlements and to ensure that 100 percent of the core levees meet the PL 84-99 standard, but the amounts needed for this would not be large, say in the order of $20 million per year.

Improvement of critical non-project and non-urban levees to a higher Delta specific standard that will provide 200-year plus protection for floods, earthquakes, and sea-level rise and that will incorporate ecologically friendly vegetation on the water side is more difficult to estimate precisely. After improvement to the Delta-specific PL 84-99 standard, levees that do not contain saturated, loose sands may come close to meeting this standard although they would still benefit from wider crowns. Additional width makes planting on the water side, which is desirable for a number of reasons and may be required by the Delta Plan, much more feasible. Determination of which levees do require additional improvement will require more detailed studies but prioritization of further improvements is relatively straightforward and does not require risk analyses or cost-benefit studies. Figure 14 provides an initial indication of which islands and tracts might be considered to have relatively high priority. These further improvements might cost in the order of an additional $2-3 million per mile. If it is assumed that this improvement is required over 300 miles of non-project and non-urban levees, the total cost might be as low as $1 billion. However, for general planning and budgeting purposes, it might be desirable to use a higher number like $2 billion. The main point is that the total cost would be $1–2 billion rather than $50 billion (obtained by multiplying 1,100 miles by $45 million per mile,

[57] Based on discussions with reclamation district engineers and DRMS Phase 2 report

the number incorrectly cited by Suddeth et al. (2008)). The biggest variable in these estimates is whether or not suitable fill is available on the same island or has to be trucked or barged in. That in turn is both a function of the availability of the materials and the cooperation of the landowners, for on-island borrowing may take some land out of agricultural production. The above estimates assume a combination of on- and off-island borrow sources. If only on-island borrow is used, these cost might be reduced by as much as 50 percent. Alternately, if the regulatory impediments to dredging in the Delta are resolved, good-quality fill material could be obtained for a cost comparable that of on-island borrow. While there are other potential uses for the dredge spoils that will results from either deepening of the deep-water ship channels or from maintenance dredging, their use for levee improvements would provide a means to keep the cost of those improvements down. These figures also assume that design and construction are executed by the local reclamation districts. If managed directly by DWR or USACE, these costs should be multiplied by a factor of as much as 2 or 3. Costs for non-urban and non-project levee improvements are much lower than costs for improvements to urban levees, which have to factor in encroachments and penetrations and where there is often no land available for widening the levees. This has resulted in the widespread use of deep-cutoff walls that are installed through the existing levees. In addition, there are significant bureaucratic issues which add to the cost, especially when there are many landowners involved. This results in the "soft costs" being as much as 50 percent of the actual construction costs on these projects. Although the possible need to take a strip of agricultural land on the Delta islands and the need to move existing drainage channels, siphons, and pumps are still issues, the cost implications are much smaller for Delta levees and only a relatively small number of landowners have to be accommodated.

The need to make the core Delta levees more resistant to earthquake loadings is a logical extension of other seismic retrofit work that has been conducted in the Bay-Delta region since the 1989 Loma Prieta earthquake. These upgrades have been performed for highways and bridges, dams, water supply systems, and the BART system. The Delta levees are the last major infrastructure element in the Bay-Delta region that needs to be upgraded to modern seismic standards. In order to put the proposed spending of a further $1–2 billion on Delta levees in perspective, it is noted that the Water System Improvement Program of the San Francisco Public Utilities Commission, which is basically a seismic upgrade of the Hetch-Hetchy aqueduct system, is costing $4.6 billion.[58]

As noted in Appendix C, there are special considerations for levees that protect Legacy Communities in the Delta. Detailed estimation of the likely cost of improving those levees awaits policy decisions that have not yet been made. However, if the levees on the relevant islands are upgraded to the proposed new Delta standard, the Legacy Communities would automatically be afforded superior flood protection.

Improved inspections and planning and positioning for flood-fighting and emergency response following earthquakes, which would contribute very significantly to a reduced risk of losses, would be very well covered by an annual budget in the order of $20 million. As noted previously, it is desirable that there be a single agency responsible for these activities.

There are three potential sources of funding from within the Delta for maintenance, improvements, and emergency response: (1) the traditional funding from the landowners, who also make in-kind contributions to inspection and maintenance; (2) the owners of the infrastructure that passes through the Delta—as noted previously EBMUD and PG&E do make

[58] http://sfwater.org/index.aspx?page=115

contributions to the upkeep of the levees that protect their facilities, but many other owners do not contribute; and (3) the agencies that convey water through the Delta. The Delta Stewardship Council has proposed the creation of a new agency, the Delta Flood Risk Management Assessment District, with fee assessment authority. Regardless of whether it is that entity or some other entity, it would be beneficial for the control of funding to pass from DWR to a more Delta-specific entity once the present bond funding is exhausted. It would also be entirely reasonable that the State and federal governments contribute funding to this entity. If it is the policy of the State to protect and enhance the Delta because that is judged to be of benefit to the region and the State, then it becomes the State's responsibility to provide funding that could, for instance, be directed primarily to widening levees so that they can accommodate vegetation on the water side. Outside its operation of the Central Valley Project, the federal government has interests and obligations that include the continuing downstream effects of hydraulic mining on federal lands, navigable waterways, and national economic security.